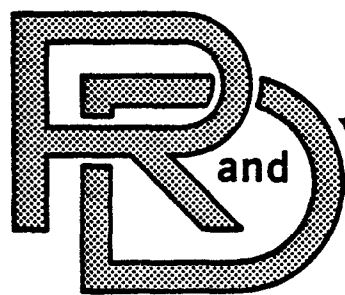


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No. 12934

MANTECH Prioritization Methodology Program

Final Report



March 1984

by Eastern Technical Division  
The Aerospace Corporation  
Washington, D.C. 20024

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## 1.0. INTRODUCTION

As a major producer of army materiel, the U.S. Army Tank-Automotive Command (TACOM) must continually evaluate its production processes, techniques, and equipment to insure that high-quality TACOM commodities are produced in a timely and economical manner in order to best support the Army Industrial Preparedness Program. This evaluation provides TACOM numerous opportunities to participate in the Army Manufacturing Technology (MANTECH) Program, which is designed to advance the manufacturing state of the art, modernize current operations, and comply with regulatory requirements. However, because these opportunities normally exceed the financial resources available to fund such projects, TACOM must exercise sound judgment in the determination of which projects to sponsor.

The purpose of this report is to develop a methodology for making this selection within TACOM. The nature of the TACOM Manufacturing Technology Program, the typical flow that results in project recommendation, and the process of project evaluation are addressed; recommendations designed to improve the process within TACOM are presented.

A method for determining the economic rank of MANTECH projects is provided as Appendix A. The evaluation parameters that are used to determine the value of a proposed MANTECH project are defined and discussed in Appendix B. The Interim Progress Report for the MANTECH Prioritization Methodology Program is provided as Appendix C for background information.

## 2.0. BACKGROUND

The Manufacturing Technology Program is a joint service program. In accordance with Department of Defense (DOD) Instruction 4200.15 (Ref. 1), manufacturing technology refers to:

...any action undertaken which has as its objective (1) the timely establishment or improvement of the manufacturing processes, techniques, or equipment required to support current and projected programs, and (2) the assurance of the ability to produce, reduce lead time, insure economic availability of end items, reduce costs, increase efficiency, improve reliability, or to enhance safety and anti-pollution measures as covered in DOD Directive 6050.1.

Also in accordance with this instruction, a particular Manufacturing Technology Project refers to:

...the development or improvement of manufacturing processes, techniques, and equipment by the

Government or private industry to provide for timely, reliable, economical manufacture of Department of Defense materiel. The objective is to bridge the gap between feasibility and full-scale production and to achieve parity between manufacturing technology and research and development advances which will smooth the translation of systems design criteria into reliable production hardware. Manufacturing technology projects may also provide engineering support to the modernization of the industrial production base to provide for improved capability to meet a military contingency. They are normally broad-based in application, are production oriented even when they are performed in a prototype environment, and are expected to result in a practical process for production. They may include the application of new or improved techniques or equipment to manufacture specific weapon systems, components, end items, and prototypes,...

As stated in a joint "Statement of Principles for Department of Defense Manufacturing Technology Program," the objectives of this program are to:

- Aid in insuring the economical production of qualitatively superior weapon systems on a timely basis;
- Insure that advanced manufacturing processes, techniques, and equipment are used to reduce DOD material acquisition costs;
- Continuously advance manufacturing technology to bridge the gap from research and development (R&D) advances to full-scale production;
- Foster greater use of computer technology in all elements of manufacturing;
- Insure that more effective industrial innovation is stimulated by reducing the cost and risk of advancing and applying new and improved manufacturing technology; and
- Insure that manufacturing processes are consistent with safety and environment considerations and energy conservation objectives.

### 3.0. MANUFACTURING TECHNOLOGY PROGRAM ORGANIZATION

The U.S. Department of the Army (DA) has an established Manufacturing Technology Program. This program is managed and controlled by the Directorate of Manufacturing Technology (DMT) within Headquarters,

U.S. Army Material Development and Readiness Command (HQ-DARCOM). Technical support is provided to DARCOM by the Industrial Base Engineering Activity (IBEA) and by the Army Materials and Mechanics Research Center (AMMRC). In addition, the Army participates in a triservice Manufacturing Technology Advisory Group (MTAG) to facilitate coordination of the diverse activities of the three military services (Army, Navy, and Air Force). Figure 3-1 illustrates the management organization for the Manufacturing Technology Program.

As a Major Subordinate Command (SUBMACOM), TACOM is responsible for managing its own Manufacturing Technology Program. Within TACOM, this program is part of the DA Production Base Support Program (PBSP), and the responsibility for it resides with the Tank-Automotive Systems Laboratory, Metals/Welding (DRSTA RCKM). This program applies to both combat and tactical vehicles. Within the Systems Laboratory, the program has been assigned the broad title of Manufacturing Technology Program, and it is conducted under the Production Engineering Measures (PEM) category of Army projects, which includes both Military Adaptation of Commercial Items (MACI) and Manufacturing Methods and Technology (MMT) projects.

#### 4.0. MANTECH PROGRAM CYCLE

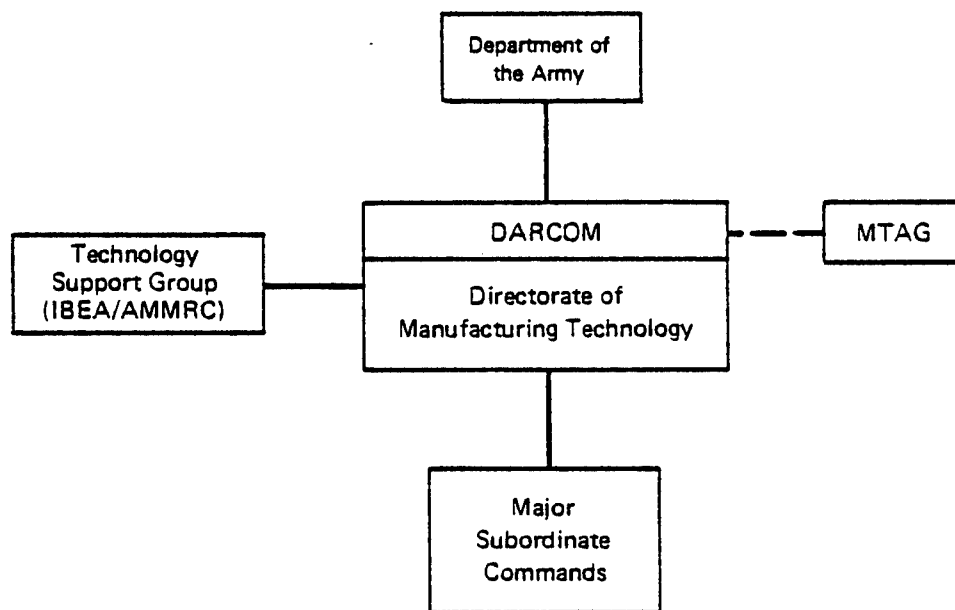
The process for planning MANTECH projects from concept through execution is highly structured and involves a number of review and evaluation steps prior to approval. In addition to representatives of DA who give final approval, IBEA, AMMRC, DMT, DARCOM, and each SUBMACOM are all active participants in the planning process. The three major activities of the planning process are the 5-year program plan, the budget review, and the apportionment review. Milestones for each activity are illustrated in Figure 4-1; the functional flow shown (for a single project) is that adopted by DARCOM for FY 1984. Details of this functional flow can be expected to be changed from time to time. However, the principal steps and responsibilities are generally retained.

##### 4.1. Five-Year Program Plan.

Each SUBMACOM maintains a 5-year program plan that is updated annually. The plan contains a summary of all projects planned to be executed within the next 5 years. During May, DARCOM (IBEA) issues a call letter to each SUBMACOM requesting that an update of the program plan be submitted by June. The program plan contains cost estimates, a description of the problem, and the proposed solution for each project. IBEA collates these plans by mission and, if necessary, by manufacturing specialties. Each SUBMACOM has, presumably, an established set of unique missions. TACOM, missions are:

- Armor,
- Drive Train,
- Body/Frame,





**Figure 3-1. Manufacturing Technology Program Organization**

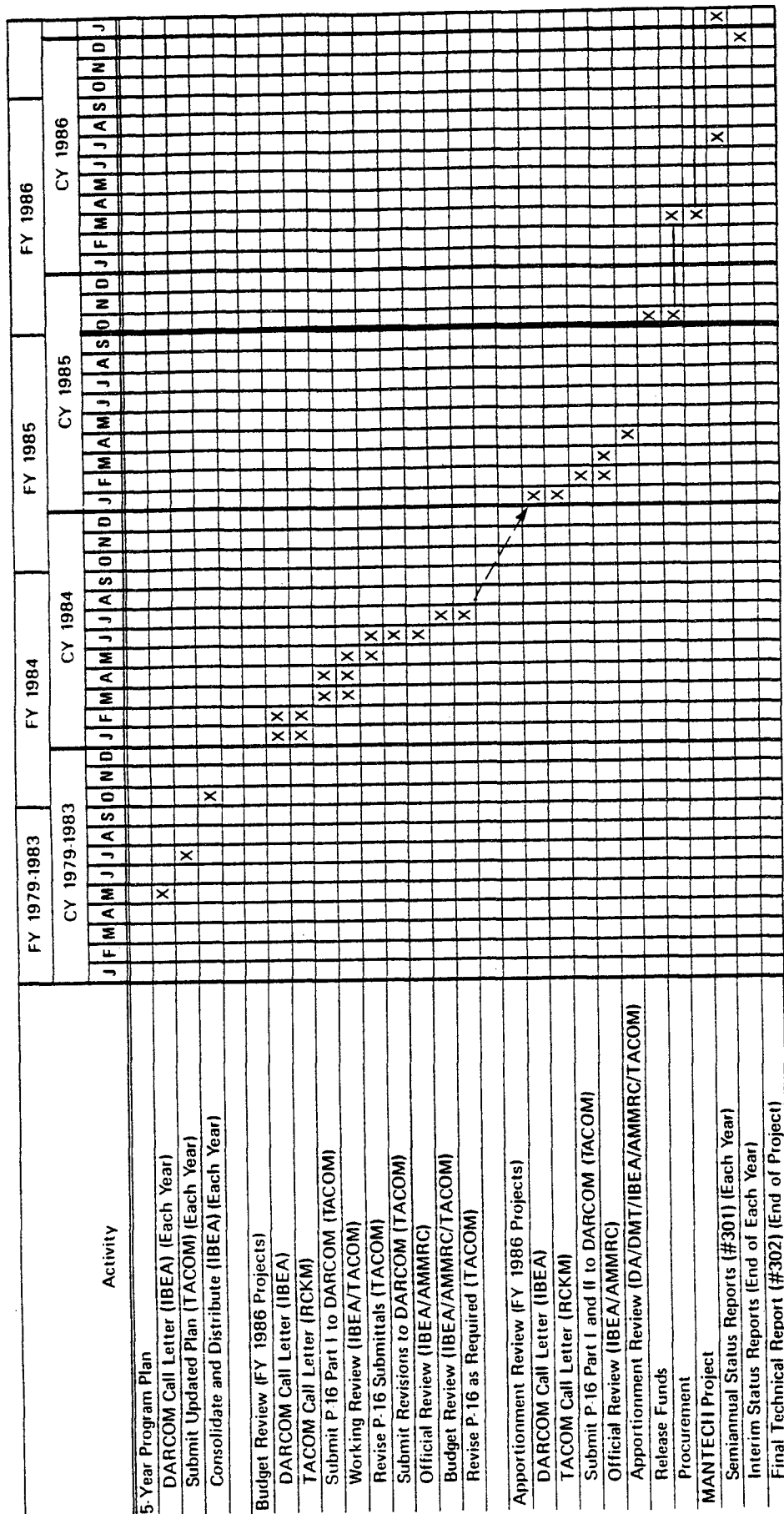


Figure 4-1. Life Cycle Milestones of MANTECH Projects

- Track,
- Suspension, and
- General.

The call letter also includes funding guidelines for each year of the 5-year period.

After receiving and reviewing these plans, IBEA consolidates them into one report representing the MANTECH effort for all of DARCOM. In October, this report is distributed to each SUBMACOM and to MTAG, among others.

#### 4.2. Budget Review.

The conduct of reviews and evaluations of new and ongoing projects and the preparation of documents to support the budget review is the next step in the planning process. The sources of new candidate projects include both government and industry, but usually arise from the manufacturing community. Obviously, those projects contained in the 5-year program plan are an initial input to the process. However, many projects planned for the outyears fall by the wayside, and new projects are submitted in their place. Ongoing projects of previous years are reviewed each year in the same manner as new projects.

The budget review process also begins with a call letter issued by DARCOM (IBEA) to each SUBMACOM early in the calendar year. This letter requests the preparation of Part I of the P-16 form (Appendix C) for each proposed project. This form is to be submitted no later than the first week of May. These proposals are for projects to be initiated 2 (fiscal) years later. Usually, these requests are relayed by the MANTECH office of the SUBMACOM to other organizations within their purview for action. The MANTECH office responsible for fulfilling the IBEA request sets its own schedule for the review, evaluation, and selection of projects to be submitted before the May deadline. In some cases, the identification and selection of candidate projects is a year-long activity.

Following submittal of the Part I P-16 form, IBEA (and AMMRC) conduct what is called a working review; usually beginning in March and extending through May, dependent on SUBMACOM response time. During this review, representatives of IBEA meet with those of SUBMACOM to discuss issues and to resolve specific questions regarding the information contained in the P-16 form.

As a result of the working review, the SUBMACOM revises individual project P-16 forms as necessary and submits a second data package to IBEA/AMMRC no later than June in support of the "official review." For this review, the total cost of all projects submitted should not be greater than 125 percent of the budget guidelines given in the call letter. During the official review, both IBEA and AMMRC prepare an independent evaluation document that is forwarded to both DMT and

SUBMACOM in support of the final budget review. Each document contains technical comments, scores each proposal, and recommends the disposition of each project. (IBEA and AMMRC use different methods of scoring, see Section 2.1.4.2. of Appendix C.) In addition to approval or disapproval, three other kinds of disposition can be recommended: (1) approve pending rewrite (A/R), which means the proposal is technically worthwhile but minor changes should be made to the documentation for better clarity or format; (2) defer for rewrite (D/R), which means the proposal has promise but the documentation is inadequate and requires major rewrite; and (3) defer for technical reevaluation (D/TR), which means the concept is good but there are technical problems to be resolved and a rejustification is required.

Following the official review by IBEA and AMMRC, the budget review is conducted in early July. The review is chaired by DMT with representatives of DA, IBEA, AMMRC, and SUBMACOM in attendance. At this meeting, final decisions are reached regarding MANTECH projects proposed by SUBMACOM. If a project is approved, SUBMACOM then schedules preparation of Part II of the P-16 form in support of the apportionment review, normally held the following April. If the project receives a contingent recommendation (i.e., A/R, D/R, or D/TR), the submittal to DMT of a revised Part I P-16 form may be required within 8 to 10 days, or consideration of the proposal may be deferred until the following year.

#### 4.3. Apportionment Review.

The apportionment review is the final step of the planning process. It begins officially with a call letter issued by DARCOM (IBEA) to each SUBMACOM, normally in January, requesting preparation of Part II of the P-16 form (Appendix C) for each project that survived the budget review and is scheduled for procurement the following fiscal year. Although a parallel process in support of the budget review for new projects is occurring during the same period, the apportionment review is held earlier than the budget review, allowing procurement to begin early in the following fiscal year.

The apportionment review is the same as the budget review, except that no working review is held. The same organizations are present at this review as were present at the budget review, and final decisions are reached as to which projects are approved for funding.

#### 5.0. TECHNICAL DISCUSSION

The following discussion presents the results of the study to develop a methodology consistent with the planning and background information.

##### 5.1. Study Approach.

5.1.1. Review of Regulations. Applicable DOD and DA regulations and other related documents were analyzed to determine the goals and

objectives of manufacturing technology programs as they might relate to the TACOM MANTECH Program. These documents also were used to formulate the major evaluation categories and subordinate evaluation parameters defined in this report. Although a composite listing of all criteria contained in these documents is quite exhaustive, it was found that there is a great degree of commonality among them. Based on this analysis, it was determined that the TACOM MANTECH prioritization methodology can be constructed from 10 evaluation parameters that can be grouped conveniently according to three categories: need, risk, and economic benefit. Further discussion of this approach is contained in Section 5.3. More detailed information on parameters contained in the applicable documents is given in the Interim Report (Appendix C).

5.1.2. Survey of Other Commands. As discussed in the Interim Report, Appendix C, visits were made to eight military organizations, other than TACOM, to assess the processes they use to select and prioritize MANTECH projects. A common element found was that all organizations generally rely on a "bottom-up" approach to originating projects, which is not unexpected because the government working-level personnel are most familiar with production problems and are closer to their industry counterpart where many of the improvements are generated. However, approximately 50 percent of these organizations attempt to define major thrust areas, convene guidance conferences, or use cost driver analyses to focus on important areas. All organizations do consider economic benefit, although it is not an overriding consideration in the prioritization of projects.

None of these organizations use a formal method of numerically weighting or ranking parameters to define priorities. Although several have attempted such an approach, no successful system has been found because there is a wide variation in project types. As a substitute, all organizations rely heavily on a peer group review process using the technical expertise within their MANTECH group, assisted in a matrix fashion by other specialists within other parts of the organization. TACOM does not currently do this. Many of these organizations also have developed a standard operating procedure or internal regulation document to guide their process. TACOM does not have such a document.

5.1.3. Analysis of P-16 Exhibits. TACOM P-16 forms were reviewed for MACI and MMT projects pertaining to weapons and tracked combat vehicles and tactical vehicles for FY 1983, 1984, and 1985. The purpose of this review was to understand the type and depth of information available to the project evaluator(s) and to assist in deriving a suitable prioritization methodology for MANTECH projects. The primary results of this analysis are discussed below.

Projects vary widely in technical scope. Some projects, such as Industrial Productivity Improvements, are quite broad and may, for example, apply to all the operations performed at a given depot.

Others, while perhaps written for a complete commodity end item (e.g., Abrams (M1) combat vehicle), may contain as many as 11 specific tasks. The project evaluation methodology must, therefore, be flexible. This flexibility was taken into consideration in developing the categories, parameters, and prioritization algorithm discussed in this report.

The majority of the projects are multiyear. More than 50 percent of FY 1984 projects were carryovers from FY 1983. A similar comparison can be made for FY 1985 and FY 1984. These carryovers may be due to funding limitations that restricted new starts. However, because this practice exists, the project prioritization algorithm developed in this report was structured to take it into account.

MACI projects are not in the same class as MMT projects. However, they represent a rather small percentage, i.e., approximately 10 percent of the projects, and it is believed that the methodology developed in this report can accommodate them.

"Productivity/Cost Savings" is the predominant benefit associated with projects. However, there is a large range of additional benefits that are often cited. For this reason, the methodology constructed in this report takes into consideration both primary and secondary benefits.

The information provided is generally adequate for a TACOM evaluator to understand the nature of the project and what the project is to accomplish. However, because TACOM has not developed a prioritized listing of needs, it is impossible to assess the importance of a particular project in relationship to others being considered. Although this information may not need to appear on the P-16 exhibit, it is considered essential to the evaluation. This feature is developed in some detail in this report.

In many cases, the depth of the economic analysis also varies as a function of the technical definition of the project. Some projects may be divided into specific subtasks where detailed cost information is available based on actual man-hours and types of operations. Other projects may be so broad in nature that only a percentage estimate of savings can be made based on the total cost of the operation as it is now performed. Return on investment (ROI) data may vary from just-profitable to more than 50 times. Due to this variance, and in consideration of the subjectivity that goes into arriving at the numbers, the prioritization algorithm described in this report was constructed to place emphasis on benefits and costs, while not allowing wide swings in ROI to potentially bias the results.

In addition, it is not clear from either the P-16s reviewed or the outline for Part II of the P-16s that the proper cost and savings values are included. The recurring savings column should be a net savings (benefits minus cost) including any operation and maintenance

costs incurred during the project life. Also, implementation costs should include not only implementing the MANTECH project, but implementing the MANTECH proven concept into mass production. This may require additional nonrecurring capital improvement costs associated with facility modifications, interruptions in the current manufacturing process, publication of new procedures or specifications, etc. Clarification of these points will insure that all projects are analyzed in a consistent manner.

## 5.2. Typical Functional Flow.

To have an effective prioritization methodology, it is considered necessary for the entire MANTECH Program to be reviewed as an ongoing process, from initial planning through project implementation and follow-up. The evaluation of proposed projects, and their subsequent ranking, then becomes an integral part of this process, as opposed to some distinct entity. Because TACOM has no formally established functional flow for its MANTECH Program, a typical, closed-loop, iterative process was developed as an aid for developing an overall prioritization methodology. This process, which can be applied to TACOM, is shown in Figure 5-1 and discussed below.

5.2.1. Monitor Commodity Manufacture. Monitoring of commodity manufacturing is essential in initiating the process of identifying and, ultimately, prioritizing candidate MANTECH projects. Cost and schedule data, safety, and other manufacturing problems in general must be monitored. This activity occurs early in the planning process and involves a rather broad participation. DMT (HQ-DARCOM) can conduct technology assessments and is familiar with future requirements and state-of-the-art manufacturing technologies. This facilitates DMT preparation of guidance packages, call letters, and ultimately, the formulation of the 5-Year Program Plan. Likewise, TACOM MANTECH representatives and Project Managers (PMs) are familiar with current and future potential problems that can be solved through the MANTECH Program. Installation personnel (plants, depots, laboratories) are closest to the manufacturing currently in process and the most likely to identify specific projects (box (5) of Figure 5-1) and, therefore, can provide feedback to the monitoring of commodity manufacture. Each organization exercises its monitoring role with an understanding of the objectives of the overall Manufacturing Technology Program.

5.2.2. Determine Improvement Areas. The results of monitoring commodity manufacturing provide the ability to determine broad technology areas where the application of MANTECH Program funds might provide the greatest benefit. These technology areas include the classic types, e.g., metals, nonmetals, automation, and electronics. A prioritization of these areas is appropriate at this point

5.2.3. Develop Forcing Functions. The development of forcing functions enables one to get closer to actual projects. For the

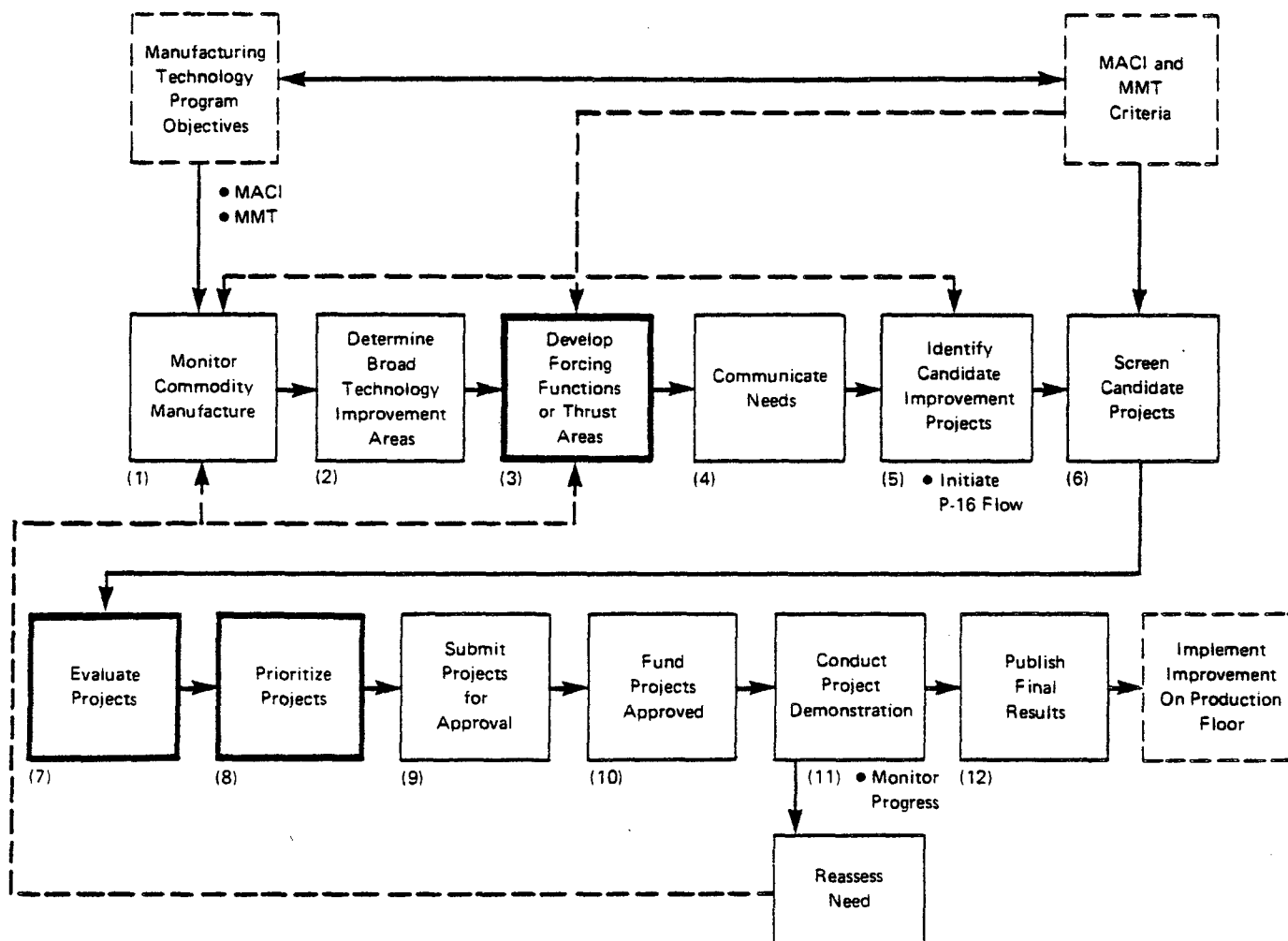


Figure 5-1. Typical MANTECH Functional Flow



commodity being considered, the technology areas identified are examined in light of forcing functions, such as complexity, high cost, and poor quality. This identification allows one to start framing a more specific objective, e.g., decrease the complexity (forcing function) in welding (technology improvement) tank bodies (commodity). To insure a greater probability of receiving appropriate candidate projects, this function is accomplished with a full understanding of the criteria for the selection of MACI and MMT projects.

5.2.4. Communicate Needs. The TACOM MANTECH office should communicate the program needs, or requirements, to the installations in order to provide them with an insight to the types of projects that are considered to be of high priority. This priority designation can be accomplished with the call letter for P-16 exhibits or can be communicated at joint seminars and conferences.

5.2.5. Identify Candidate Projects. The identification of candidate projects initiates the P-16 flow, which is normally performed by the installation that originated the proposed project. As discussed in Section 5.2.1., installations can, however, have a role earlier in the process through the development of technology areas and forcing functions. Again, this function is performed in recognition of the criteria for such projects.

5.2.6. Screen Projects. Early screening of candidate projects at the installation level is important in helping to eliminate projects submitted to the TACOM MANTECH office; additional screening also will be performed at the MANTECH office level. This function is essentially a go/no-go screen against the established criteria for these projects. Those criteria include (Ref. 2, DARCOM Handbook, defines the first five criteria):

- Military Department Requirement: Every project must satisfy a current or anticipated Military Department requirement for which manufacturing techniques are needed. Future requirements normally will be qualitative in nature and will be directed toward the adoption of manufacturing technology that will increase general productivity.
- No Duplication of Effort: The problem solution must not be otherwise available on a timely basis from other known programs undertaken with government support or private capital.
- Manufacturing Technology Problem: The problem solution must require the establishment of new, improved, or more economical manufacturing processes, techniques, or equipment rather than basic R&D-oriented efforts on the mere application of existing processes, techniques, equipment, or facilities for the manufacture of specific parts.

- Adequate State of the Art: Qualitative, laboratory type feasibility of the effort under consideration must have been demonstrated sufficiently by experiment or extrapolation of analytical data.
- Worthwhile Benefits: Determination must be made that a project normally will result in one or more of the following:
  - Improved responsiveness to current and projected requirements,
  - More effective industrial preparedness base that will reflect modern manufacturing techniques and result in improved defense production posture, and
  - Timely manufacturing technology development to provide information to be used in preparation of material specifications or contract definitions that reflect the most advanced manufacturing state of the art.
- High likelihood of implementation in both government or industrial facilities.
- Satisfy a stated requirement through the adaptation of a commercially available (domestic or foreign) item, generic component, or system.

5.2.7. Evaluate and Prioritize Projects. Evaluating and prioritizing candidate projects is a most important function. This function is performed by applying those parameters discussed in Section 5.3., using the methods given in Sections 5.4. and 5.5. It may be performed as part of a joint evaluation team or can be performed exclusively within the higher levels of TACOM. At this point, IBEA can be brought into the process so the evaluating personnel benefit from its broader perspective of projects being pursued within other SUBMACOMs.

5.2.8. Submission for Approval. Candidate project suggestions must be submitted to DARCOM for final approval. This submittal occurs in two steps: initial submittal in July as part of the budget and planning cycle and again in April of the following year for the apportionment cycle where actual funding is approved for specific projects.

5.2.9. Conduct Demonstration. Following project approval and program and fund release, TACOM assumes overall responsibility for project execution. Until the project is complete, TACOM will provide a MANTECH Program Project Status Report (RCS-DRCMT-301) to IBEA and DMT. These reports are submitted by January 15 and July 15 of each year. IBEA reviews the project status and makes a consolidated report with recommendations. The consolidated report is forwarded through HQ-DARCOM to Headquarters, Department of the Army (HQDA).

In addition to publishing status reports, the action agency is responsible for closely monitoring the progress of the project. This monitoring allows for a reassessment of the value of the project and the opportunity for feedback to the development of forcing functions for new projects. During a subsequent year evaluation process, an ongoing project may be determined to have a lower evaluation than newer projects. If this occurs, and funding limitations will not allow pursuing both, a decision may have to be made as to which one to pursue. This situation will have to be evaluated on a case-by-case basis taking into account the following factors:

- Percent of total planned investment expended;
- Success to date in terms of performance, cost, and schedule;
- Cost of termination;
- Loss of benefits if project is not completed; and
- Impact of delaying new project.

5.2.10. Publish Final Results. Upon receiving the final MANTECH Project Status Report, IBEA completes a Summary Report (RCS-DRCMT-302) highlighting necessary implementation actions and possible uses by other commands and services. This report is disseminated to all activities having technical interest in the results. In addition, the action agency may provide a technical report for those projects of generic application or of high technology interest. IBEA screens these technical reports and selects those suitable for publication by the National Technical Information Service. At this point, the responsible SUBMACOM takes the necessary action to implement project results.

### 5.3. Proposed Evaluation Parameters.

All MANTECH projects can be evaluated by parameters that fall into three categories: need, risk, and economic benefit. These parameters, illustrated in Figure 5-2, can be combined, as discussed in Section 5.5., to determine the priority or rank of the project.

5.3.1. Need. All MANTECH projects should be designed to satisfy a documented Army need to improve a particular manufacturing process, technique, or equipment in a manner that has broad applicability not only within the Army but also within other branches of the Armed Forces, as well as in private industry. This need is derived from experience with, or analysis of, the ongoing manufacture and maintenance of existing or modified military systems, as well as the requirements imposed by new military systems entering the acquisition cycle.

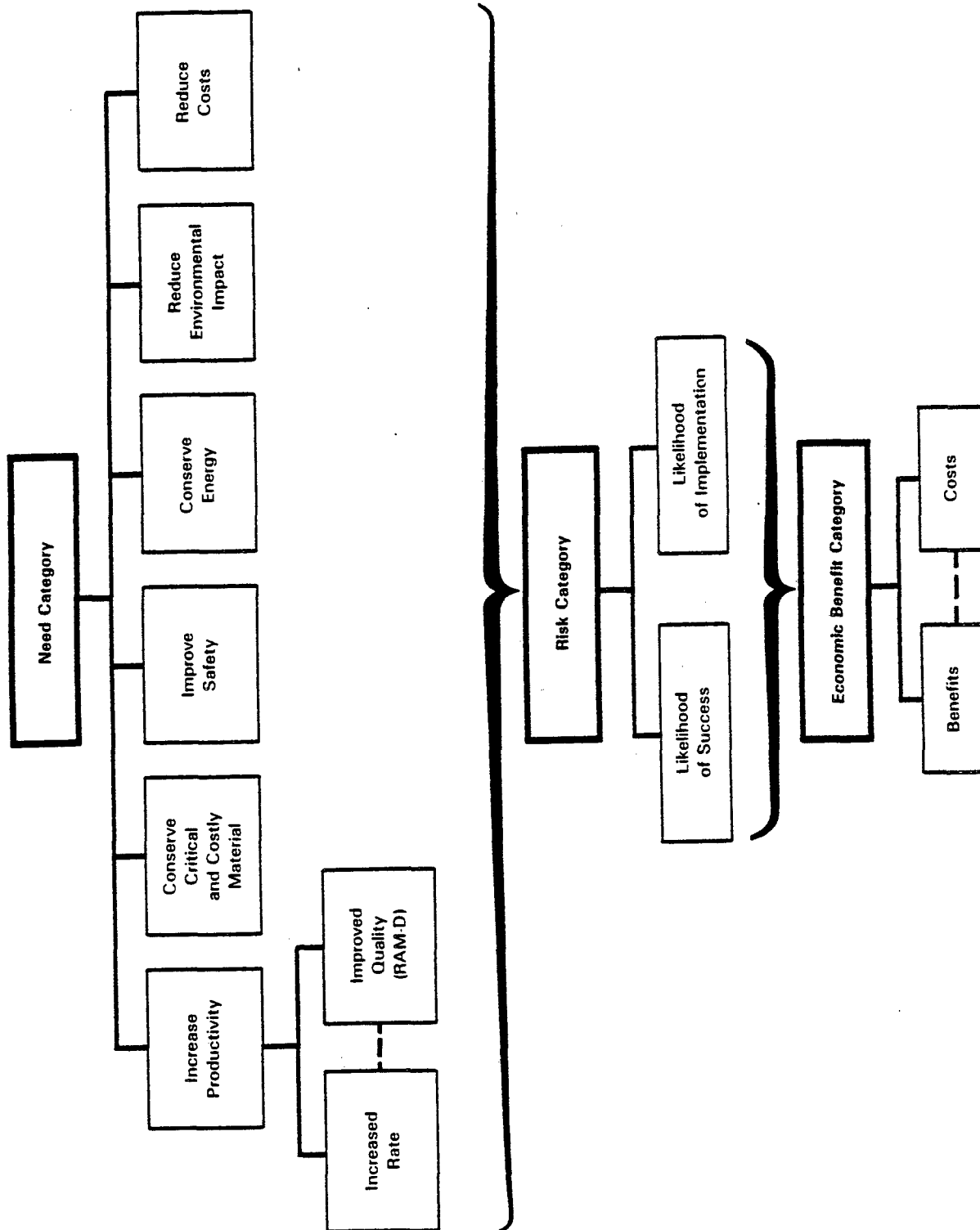


Figure 5-2. Categories of Evaluation Parameters

Need is the most important parameter in evaluating TACOM MANTECH projects because it focuses on solving existing problems or providing solutions for potential problems. Existing manufacturing bottlenecks, new system designs (including material changes), new system performance requirements, mission support requirements (readiness, mobilization), material shortages, and maintenance problems contribute to the creation of a need for MANTECH projects. The criterion of economics also can be expressed as a need (e.g., the need to reduce costs), although it is more generally used as a measure of merit in evaluating competing projects. Typical candidate manufacturing areas that generate a need for the application of MANTECH resources include:

- Labor-intensive operations;
- Operations that generate high waste, particularly of scarce and high-cost material;
- Complex operations that can be consolidated, eliminated, or streamlined;
- Operations with low production yields, where improvements will reduce rejection rates;
- Dangerous manufacturing operations (e.g., toxic materials handling, explosives, pollutants, and equipment); and
- General high-cost areas, other than those cited above, where it is known that a particular manufacturing phase represents such a large percentage of costs that any improvement (management-material-process) will have a payoff in dollars saved.

General objectives or parameters that typify need are

- Increase Productivity: Increase Production Rate or Improve Quality (reliability, availability, maintainability, and durability (RAM-D)),
- Conserve Critical/Costly Material,
- Improve Safety,
- Conserve Energy,
- Reduce Environmental Impact, and
- Reduce Cost.

Definitions for these parameters are contained in Appendix B. Reducing costs is included because it may drive a specific need. However, reductions in cost are generally realized by satisfying one or more of the other objectives. In these instances, cost reductions

are treated separately under economic benefit. A project also may have secondary benefits by satisfying other needs. For example, a project that reduces the cost of curing composite materials also may improve safety or reduce environmental impact. In these cases, extra credit is given in the evaluation, as discussed in Section 5.5.

The establishment of needs should occur on an annual basis. Although participation in this effort can come from anywhere within TACOM, or its related organizations, it is essential that the TACOM MANTECH office take the lead in establishing the list for it to serve as effective guidance in the solicitation of MANTECH proposals.

Needs should be succinctly stated and, as described in Section 5.2., should be based on:

- Forcing Function,
- Technology Area,
- Subsystem or Component of the Commodity, and
- Commodity.

Examples of such statements of need include

- Improve safety (forcing function) in applying caustic anticorrosion paint (technology area) to all tracked combat vehicles (commodity),
- Improve the quality (forcing function) of manufacturing (technology area) track shoe pins (component) for M1 tanks (commodity), and
- Reduce the cost (forcing function) of curing composite materials (technology area) for turret baskets (subsystem or component) of the Abrams tank (commodity).

Once the total list of needs is established, it is necessary to prioritize them. Again, upper management participation is recommended because (1) it may be necessary to cross lines of equal authority to establish priorities and (2) endorsement of the list is beneficial. In establishing priorities, consideration should be given to the following criteria.

- Urgency. What is the impact on the TACOM mission if this need is not satisfied? Something that could jeopardize readiness or mobilization requirements would be more important than something that just reduces costs.
- Timeliness. Where in the acquisition cycle is the hardware for which the improvement need has been established? In most

cases, the earlier the need is satisfied, the more effective it will be. However, there also may be cases where the need is so great that it should receive a very high priority or it will not be satisfied before the production run is completed.

- **Genericness.** Is it a broad need that applies to several commodity items, subsystems, or components, as opposed to a unique need where the proposed solution may be less likely to have generic application?
- **Interest.** Are there other branches of the military or private industry that may be pursuing projects based on a somewhat similar need? Would joint participation or cofunding with another branch of the service be possible? Is it likely that the need would be satisfied in the near term without TACOM pursuing it aggressively?

5.3.2. **Risk.** Parameters used to quantify risk have been limited to likelihood of success and likelihood of implementation. These parameters are defined in Appendix B. All MANTECH projects will encounter some degree of risk. This risk is an estimate of the probability that a given project may not achieve its stated goals or objectives, from project initiation through actual implementation in full-scale production. In essence, it is nothing more than a reflection of the uncertainty band around key evaluation parameters whether they are technical or economic. For example, projects will be submitted in response to the factors described in Section 5.3.1. that typify need. However, there is always the chance that the project may not fully satisfy the need, or that its technical feasibility will not prove worthy of incorporation into full-scale production. Also, even if technical feasibility is proven, there is always some risk that the improvement may not be implemented for reasons that may go beyond the control of the MANTECH organization. Therefore, there is a definite uncertainty associated with success and implementation.

Economic cost and benefit estimates also are likely to contain some risk, as financial estimates are nothing more than projections at the early stage of project submittal. However, this weakness will be common to all projects submitted. Therefore, relative comparisons of projects will be consistent, and there is no reason to become overly sophisticated in attempting to bound financial figures that are known to be estimates. Furthermore, for multiyear projects, this risk is reduced with time as new economic analysis data are produced each year.

There is a positive correlation between the technical risk of success and economic risk. The greater the technical risk, the greater the likelihood that (1) it may cost more than projected, even if successful, and (2) that funding may be invested continually in the project in pursuing modifications that may make it successful, when in reality, it should perhaps be dropped.

### 5.3.3. Economic Benefits and Costs.

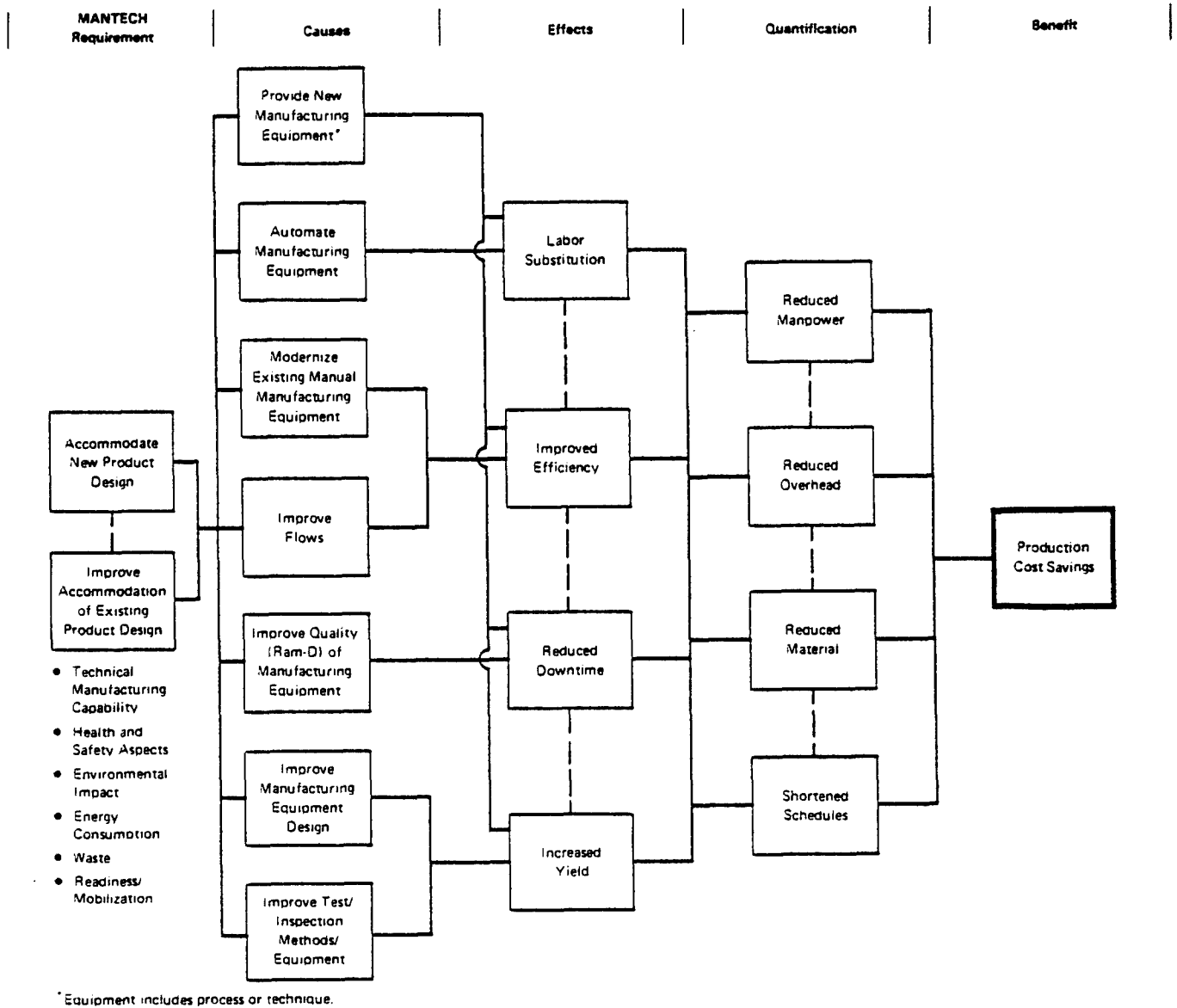
5.3.3.1. Benefits. For the case of TACOM MANTECH projects, the economic benefit is purely one of cost savings. The manufacturing work must go on, and there are no alternative investment scenarios or profit motive incentives that apply. Therefore, production cost savings become the bottom line; it is important to understand the traceability from need to the dollars that are saved. Figure 5-3 is a simplified flow that illustrates this traceability; it shows that most economic benefits can be quantified. It is essentially a cause and effect relationship for MANTECH projects.

As illustrated in Figure 5-3, all MANTECH projects are originated to improve the manner in which an existing commodity is being manufactured or to arrive at a method for manufacturing some new commodity design. These two objectives also are interrelated in that the manufacture of an existing commodity may be altered by just a change in product materials, as opposed to an entire new product design.

These MANTECH requirements can basically be satisfied by new or modified (including improved quality) equipment, improved factory flow, or changes in test and inspection. These changes, in a sense, then become causes that either taken singularly or in combination will have an effect on the current method of production. These effects usually appear in the substitution of labor or in general, increased productivity due to operating more efficiently, reducing the downtime or increasing the yield. There is an interrelationship between these effects as any one of them might also contribute to another, e.g., reduced downtime will certainly increase yield. It also should be noted that the causes are all branched together leading to the effects because there is more than a one-to-one correlation between cause and effect. For example, improved quality of manufacturing equipment can reduce downtime and, in turn, increase yield.

Each of the effects can be quantified in measurable changes in manpower, overhead, material (kinds and amounts) and shortened schedules. It may require a great deal of research to derive these quantities, and of course, the precision surrounding the answer is directly proportional to the effort put into obtaining it. The analyst may have to examine the Work Breakdown Structure (WBS) for the item being produced to determine which specific element(s) are affected and to what degree. Again, there is an interrelationship between the quantified answers; e.g., a reduction in man-hours required may result in a reduction in total manpower, which should reduce overhead. For most TACOM projects, this traceability should be quite straightforward and values should be derived easily because they are first-order effects, e.g., the amount of time saved by an individual no longer required due to automation is a relatively easy number to determine. Other changes, such as improved health and





**Figure 5-3. Flow of Quantifiable and Tangible Benefits**

safety, are second-order effects and, although they may be traceable, are difficult to quantify. The effects of fewer accidents, fewer days lost due to illness, etc., may be inherently obvious, but may yield insignificant answers in an economic analysis. In these cases, more emphasis should be placed on demonstrating an ability to meet a priority need at low risk than on factors of second-order influence in the evaluation.

The quantifiable effects can, in turn, be expressed in dollar amounts, e.g., man-hours times labor rate, pounds or feet of material times unit costs. The aggregate of these dollar amounts then becomes the production cost savings, which is the benefit to TACOM.

5.3.3.2. Costs. Assuming one has pursued the traceability of the manufacturing change and has arrived at a "production cost savings," the only remaining element that has to be considered is the actual cost of the change; i.e., hardware and facility procurement and construction, etc. Cost savings is a benefit, but to make this a "net" benefit, the cost of implementation must be considered. Another way of saying this is that production cost savings are often pretty much "operational" costs; i.e., the line is up and running, and the only thing compared is running it the existing way versus the improved way. This type of analysis tends to ignore acquisition and start up costs and perhaps operation and maintenance.

Although cost figures may seem easily obtained, often provided by a reputable supplier of the improved equipment, considerable attention should be given to their derivation. Several things should be considered. First, is the forecasted operation and maintenance for the new equipment and how favorably it compares with existing equipment. This may have been considered in the cost savings analysis (e.g., higher quality equipment, less downtime, greater yield). Given that MANTECH demonstrations may involve only a 1- to 3-year effort, not much opportunity is afforded to build a historical data base, such as exists for the current equipment; therefore, this estimate may be crude. Second, what is the likelihood that the existing equipment will soon have to be replaced, even if not improved; net costs may be reduced if the choice also must consider buying another of the old, as opposed to obsoleting the old and buying new. Third, and most important, the cost estimate should consider actual implementation of the improvement in long-term mass production, as opposed to just the costs of conducting the MANTECH project. Pilot demonstrations do not have the same impact as full-scale development changes in the main production line; this relates to the ease of implementation, which is further discussed in B-2.2.

#### 5.4. Proposed Evaluation Procedures.

The methods used for evaluating and ranking candidate projects must not ignore the total process of developing and implementing MANTECH projects (as represented in Figure 5-1). Consideration should be

given, therefore, to the manner in which proposals are solicited and to the screening factors to be applied to them before submission for review, as well as to the actual evaluation and ranking procedures. The purpose of considering the total MANTECH process is to develop a standard operating procedure that complies with the MANTECH mandate at TACOM. The procedure should be known to all participants in order to maintain a continuity of effort and an accountability such that each proposal is handled equitably. Standardization is of importance because of the diversity of candidate projects that must be evaluated. In addition, the procedure must be flexible to accommodate changes that may occur in the policies and guidelines set by higher authority to give overall definition of the MANTECH Program.

The documentation and current program cycle schedule discussed in Section 4.0. also is subject to change. For example, the two separate parts of the P-16 form, with separate review cycles, was instituted for the first time in 1983. The MANTECH organization of TACOM responsible for these procedures must have a method for informing all parties of changes in the process and develop guidelines to respond to these changes. The real possibility of major changes in the definition and implementation of MANTECH efforts underscores the need for not only a systematic process that is documented for all to follow, but also a systematic method for modifying the process in a timely manner. The important phases of this process are discussed below.

5.4.1. Proposal Solicitation. The objectives of the proposal solicitation phase should be to obtain proposals that (1) meet a significant need of TACOM, (2) involve effort clearly within the province of MANTECH funding, and (3) provide the information necessary for evaluation without ambiguity. Meeting these objectives reduces the time and labor required for review and evaluation. One way of promoting these objectives is to provide clear guidelines and support to those preparing proposals and to maintain a year-round contact and liaison with those groups, both government and industry, whose function is the manufacture (or purchase, if MACI remains a part of MANTECH at TACOM) of TACOM commodities. The explicit manner in which this support and contact is achieved depends, of course, on the organization and the way of doing business that each SUBMACOM has developed. There are, however, elements of this activity that are of importance to any group that expects to develop and promote quality MANTECH projects that also are responsive to the SUBMACOM mission. These elements include

- Definition of priority needs,
- Definition of screening criteria,
- Definition of proposal format, and
- Solicitations of new and ongoing project.

5.4.1.1. Definition of Priority Needs. It is very important for TACOM to develop a priority listing of MANTECH needs. Without such a listing, the evaluation and ranking of candidate projects tends to become more subjective; thus, the program can be less responsive, more fragmented, and the results less utilized or implemented. As discussed in Section 5.3., need is identified as the most important evaluation parameter. The selection and ranking of TACOM needs should receive the same emphasis and support for MANTECH as does the acquisition process for major new systems.

The MANTECH office of TACOM should take the lead in developing a prioritized list of needs for the MANTECH Program. This lead may be developed through discussions with those directly involved or responsible for the manufacture, maintenance, or purchase of TACOM commodities. The prioritized list of needs should be updated annually. The definition of needs should strike a balance between the specific and the general, as noted in Section 5.3.1. Section 5.3.1. also suggests a procedure for developing the priority of needs once they have been identified.

5.4.1.2. Definition of Screening Criteria. A clear statement of the type and scope of effort that bounds the MANTECH Program must be provided to the individuals who conceive and develop MANTECH projects. In view of the considerable variety of interpretation of what constitutes MANTECH observed during the survey of commands, the development of screening criteria compatible with the mission of TACOM is of great importance.

These criteria do not define the utility of a candidate project but are used to reject projects that are outside the current definition of MANTECH. While they are not sacrosanct, these criteria are very useful in aiding the efficiency of both the proposer and evaluator. Section 5.2.6. provides a listing of typical criteria obtained from the survey of commands and the open literature, which may or may not fit the needs of TACOM. A frequently overlooked criterion is that the project must not improve or affect the design or performance of an end item, but only the manufacture of an end item.

It is required that the MANTECH group at TACOM develop and maintain a set of criteria that fits the current definition of MANTECH while also meeting the needs of TACOM. Determining the current definition of MANTECH may be difficult, but some defensible assumptions must be made and validated as required by the local chain of command. These issues and decisions must be identified in the beginning and made visible to all participants in the MANTECH process.

5.4.1.3. New and Ongoing Project Solicitations. The solicitation of new and ongoing projects requires different emphasis. New, worthwhile ideas are difficult to find and need effort to cultivate, as with any other rare commodity. In recognition of this, some commands (e.g., Materials Laboratory, Air Force Wright Aeronautical Laboratories

(AFWAL)) pursue the identification of new projects on a year-round basis. Other commands conduct seminars and meetings periodically to present ideas and discuss problems. Briefings also are conducted to inform industry of command needs and opportunities. It does seem prudent to give the listing of TACOM needs a wide distribution.

Continuing projects as well as new projects are evaluated each year. The evaluation of these projects should consider the technical status and phase of each in addition to other parameters. Because neither Part I nor Part II of the P-16 form contains an entry regarding project status, TACOM's request for these forms may ask for an addendum to provide these data if it is determined necessary. Separate project status reports are currently provided to the MANTECH group semiannually. Of interest to evaluators are (1) whether the milestones have been maintained and deliverables provided successfully, (2) the technical problems and their prognosis, (3) the growth rate of costs, and (4) the percentage of funding expended. A project that is demonstrating progress in meeting objectives on time and in budget would normally receive extra credit over the claims made in the proposal for a new project. The evaluators need knowledge of status to properly rank ongoing projects with new projects, and such information should be requested and made available to evaluators.

5.4.2. Request for Proposals. The process for implementing quality proposal measures is initiated with a memorandum to the individuals or groups known to be potential sources of projects and in this respect is the same as any other RFP. The memorandum, or call letter, should contain:

- A priority listing of TACOM needs;
- Screening criteria and definitions or clarifications of the MANTECH Program, as appropriate;
- A copy of the DARCOM guidelines, if appropriate, and P-16 forms;
- TACOM guidelines, as appropriate; and
- Due dates and points of contact in the MANTECH group.

It would be well to also include the evaluation parameters to be used and a brief summary of the evaluation and ranking process to be used. This memorandum should be issued soon after the updated priority listing of needs has been distributed, anticipating the budget and appointment review cycle of Figure 4-1.

The MANTECH office should review each proposal as it is submitted to determine (1) clarity and completeness of the data provided, (2) adherence to the guidelines established previously by IBEA and TACOM, and (3) that each passes the screening criteria for MANTECH projects.

The determination of eligibility by screening criteria may be judgemental in some cases. In these cases, the review should go in favor of the proposal, with the final determination made in the evaluation described below.

5.4.3. Review and Evaluation. It is proposed that the MANTECH group at TACOM establish a review group to aid the evaluation and ranking of projects. Although the conduct of the group may be informal, the following characteristics of its operation are recommended to help approach the desirable goal of all juries, i.e., objectivity with equity. In this instance, selection for success is the real objective, but elusive. One can only hope that with proper selection of evaluators, objective and equitable procedures will insure a reasonable success rate.

5.4.3.1. Evaluator Selection. The MANTECH group should identify the kinds of expertise required to assess proposals submitted in response to the needs list. It is suggested that the review group consist of permanent members who are informed generalists with mature judgment. Ideally, each permanent member should have hands-on expertise in some aspect of manufacturing that compliments the expertise of other permanent members and should be familiar with a variety of manufacturing processes and techniques, particularly those related to the priority needs of TACOM. In addition, ad hoc members can be called in as necessary to augment the panel expertise. The panel size should be small enough to be efficient and large enough to insure coverage of the majority of technical issues, possibly 5 to 10 members.

The review panel should be chaired by a representative of the TACOM MANTECH office. The chair is responsible for all activities related to evaluation, including recruiting members, setting agenda and schedule, developing procedural rules considered necessary, conducting review panel meetings, and recording findings.

5.4.3.2. Agenda Preparation. The chair determines the agenda for each meeting and distributes it sufficiently in advance for each evaluator to prepare for the meeting. The agenda of the first meeting of the review group should be accompanied by a complete data package containing all the information previously supplied to the proposers. (If the evaluators are identified and recruited in time, they could be provided information copies of the RFP package.) Of particular importance is, of course, the definition of the evaluation and ranking techniques to be used and a copy of each proposal to be evaluated. The latter will have been checked for gross errors or omissions prior to distribution.

A major function of the agenda is to establish the order in which the projects are to be considered initially. Whatever the order adopted, there could be an advantage to considering the group of ongoing

projects first because some of the new projects may be closely related to or duplicate those of ongoing projects. It also would be useful to group projects that are related or propose to satisfy the same need.

5.4.3.3. Conducting Meetings. The chair should not only determine the agenda, but also must exert authority to insure it is followed. At this time, it should be determined that all understand the methodology to be followed in evaluation and ranking (Section 5.5.).

It is recommended that the evaluation and ranking of projects be conducted as follows.

- The first meeting of the review group should be brief and limited to a review of the data package (Section 5.4.3.2.) distributed previously. To increase efficiency, it is suggested that the MANTECH office group select proposals prior to this meeting, allowing the chair to assign a group of projects to each member that is compatible with his or her expertise. The purpose of this assignment is to ascertain facts about each project that are pertinent to its evaluation. The facts to be established include the status of continuing projects, TACOM needs the project is to meet, technical feasibility or relation of the technology involved to the state of the art, validation of economic factors, if screening factors are violated, etc. Each member can present these facts at the next meeting, thereby allowing more time for evaluation.
- Subsequent meeting(s) are devoted to evaluation and ranking of projects using the algorithm defined in Section 5.5. Each expression in the algorithm should be scored for each project in turn, as opposed to completing the entire algorithm for each project. This technique improves the relativity of ranking by forcing the evaluator to concentrate on a single category of parameters for all projects. All members of the group participate in this process, based on each member's interpretation of the facts presented previously. The average values are then incorporated into the complete algorithm and a final score is calculated for each project. This score provides the ranking order of all projects with the highest priority project receiving the highest score.

5.4.3.4. Recording Results. A permanent record should be kept of the results of the evaluation. In addition to the rank and score of projects, a record of the minutes of each meeting should be maintained. The minutes should be available to members at the next meeting for confirmation, comment, and use as a mnemonic. The minutes are useful for preserving continuity in the evaluation process, for accountability of results, and can be useful in improving the process.

### 5.5. Proposed Ranking Algorithm.

The number of ways the evaluation parameters can be manipulated to achieve numerical figures of merit suitable for ranking is enormous. It must be remembered that the relationships between the evaluation parameters and the weights, or numbers, applied to them are established in an arbitrary manner and are limited only by the imagination and preferences of the originator. The only rule is the logic that a positive feature of a project increases its rank and a negative feature reduces its rank. Therefore, the scoring algorithm defined herein is considered to be merely a tool to simplify the task of determining an initial rank order of a large number of candidates (approximately 30 to 40). It allows the consideration of features one at a time instead of all at once. The imposition of limits on the values, or weights, applied to parameters provides some objectivity to the ranking because the values are applied equally to all projects. The subjectivity of judgment enters in making the estimate of the value of a parameter within these limits.

The algorithm proposed for prioritizing TACOM MANTECH projects is based on combining the three major categories of need, risk, and economic benefit, taking into account the individual parameters that make up these categories. In addition, a "status factor" was incorporated into the algorithm to better account for the known performance of ongoing projects.

The interpretation of the scores obtained with the proposed algorithm is only that of rank order; the differences between scores, or actual values obtained, are usually not important. Therefore, the arithmetic required to calculate the score has been kept simple. The proposed algorithm recommended for ranking, or prioritizing TACOM MANTECH projects is:

$$\begin{array}{ccccccc} \text{Need} & & \text{Risk} & & \text{Economic} & & \text{Status} \\ & & & & \text{Benefit} & & \\ \left[ \frac{100 (R_n + B_n)}{n} \right] & \times & [P_S \times P_I] & \times & [S_I] & \times & [S] \end{array}$$

The expressions in the algorithm, and the suggested values or limits to be applied to each of the terms, are developed in the following sections. Table 5-1 summarizes these values and the limits that are applied to each term of the algorithm. The ratios of maximum to minimum values are also shown. Because the algorithm is a product of terms, these ratios are indicative of the influence each has in establishing rank. As can be seen, the values of these ratios for the category of need (7.5 N), risk (16), and economic analysis (3.3) are roughly equivalent in magnitude, such that no single category always takes precedence.



Table 5-1. Characteristics of Scoring Method

Parameter	Symbol	Algorithm	Range		Ratio
			Minimum	Maximum	
<u>Need</u>					
Priority of Need	n	100/n	100/N	100	N*
Relevance of Project to Need	R <sub>n</sub>		0.2	1.0	
Secondary Benefit	B <sub>n</sub>		0	0.5	
Degree of Meeting Needs		(R <sub>n</sub> + B <sub>n</sub> )	0.2	1.5	7.5
<u>Risk</u>					
Likelihood of Success	P <sub>s</sub>		0.2	0.8	4
Likelihood of Implementation	P <sub>I</sub>		0.2	0.8	4
<u>Economic Benefit</u>	S <sub>I</sub>	$10 \left\{ \left( \frac{\sum_{i=1}^i B_i}{\sum_{i=1}^i C_i} \right) \div \left( B_i / C_i \right)_{\max} \right\}$	3.0	10	3.3
<u>Status</u>	S	(ongoing projects) (new projects)	0 1	2 1	
Score = 100{(R <sub>n</sub> + B <sub>n</sub> )/n} (P <sub>s</sub> • P <sub>I</sub> )(S <sub>I</sub> )(S)			0	1920	

\*Total number of priority needs.

5.5.1. Need Parameters. The algorithm developed here assumes that a ranking of the needs, or forcing functions, for TACOM has been established. Let the ranking order of TACOM needs be numbered 1, 2, ..., N in order of priority, with 1 indicating the highest priority, n indicating the priority of the nth need in the list, and N indicating the lowest priority. If it is determined that the project under evaluation is proposed to meet a need of priority n, its importance can be represented by  $100/n$  (to eliminate small decimals). This value is then modified by two factors; viz., the relevance of the project to meeting the need ( $R_n$ ), and the secondary benefits ( $B_n$ ) that may accrue in meeting the need.

$R_n$  is a measure of the degree to which the project meets need "n." It is conceivable that the project only attacks part of the problem represented by n, or that its schedule may not exactly meet the time table of need "n." In those rare cases where a project appears to aid in meeting more than one primary need, it can be scored under each need met and the results added. A secondary benefit,  $B_n$ , is one not included in the TACOM needs list or one to which the project was not directed, but that is of general benefit to the military production base. The establishment of a project whose justification is to satisfy the need to reduce the cost of curing composites also may increase safety and reduce pollutants of the process.

Let  $R_n$  and  $B_n$  assume the values

$$\begin{aligned} 0.2 &\leq R_n \leq 1.0 \\ 0 &\leq B_n \leq 0.5 \end{aligned}$$

The choice of these interval bounds can be defended as follows. The relevance of the project ( $R_n$ ) should be greater than 10 percent, or it should not have been identified with n. An upper bound of "1" indicates that the project, if successful and implemented, will eliminate need (n) from the list. If this success and implementation provides a secondary benefit(s), it also then receives a credit of up to 0.5. Because these are secondary benefits, their value should be less than that of meeting the prime need, as measured by  $R_n$ . Obviously, if there are no secondary benefits,  $B_n$  becomes zero. Finally, the values allocated to the project for relevance and secondary benefit(s) are added and multiplied by the importance factor ( $100/n$ ) to give its score for the evaluation category of need. Thus

$$\text{Need} = 100 (R_n + B_n)/n.$$

5.5.2. Risk Parameters. There are two kinds of risk involved. The first, technical feasibility, is measured by the likelihood of success ( $P_s$ ) in establishing a viable, new or improved manufacturing technique, process, or equipment. The second, implementation, can be measured by the likelihood of implementation ( $P_i$ ). Although the likelihood of implementation also depends, to some extent, on the

likelihood of success (discussed in Appendix B), there are other factors that can determine if a project is to be implemented, even if successful. Let  $P_S$  and  $P_I$  assume the values

$$0.2 \leq (P_S, P_I) \leq 0.8$$

on the grounds that projections of this nature cannot be certain, good or bad. The likelihood of success and implementation are then multiplied to obtain an estimate of risk. Thus

$$\text{Risk} = P_S \cdot P_I$$

5.5.3. Economic Benefit Parameters. The next expression in the algorithm is one that determines the value, or weight, of economic rank. As developed in Appendix C and Appendix A, the benefit to cost ratio (or savings to investment ratio) was selected as the economic measure of merit. However, because there is a potentially wide range in these ratios, it was determined that some form of index should be developed to make the economic component of the ranking algorithm consistent in scale with other elements of the algorithm. This consistency can be achieved by normalizing the values of the cumulative benefit to cost ratios as follows

$$10 \left\{ \frac{\sum_{i=1}^i (B_i) / \sum_{i=1}^i (C_i)}{(B_i/C_i)_{\max}} \right\}$$

where the numerator of the index is the cumulative benefit to cost ratio summed to the  $i$ th project of the set being evaluated and the denominator is the maximum, individual benefit to cost ratio of the set. In this notation, " $i$ " represents the economic rank of a given project, with  $(B_i/C_i)_{\max}$  representing the project with the highest individual B/C ratio. As developed in Appendix A, the economic rank is determined by a computational routine that compares projects in pairs (recommended if computer facilities are available) or by the less effective method of comparing individual benefit to cost ratios.

With either method, the use of incremental cumulative ratios rather than individual benefit/cost ratios is recommended because it represents the total benefit to cost ratio that can be realized by the subset of projects to be funded. It also provides more orderly increments between ranks. (See Table A-1 of Appendix A).

The upper bound of the economic index is 10 because it is normalized to the maximum ratio. (As with need, the multiplier 10 reduces the prevalence of small decimals.) Theoretically, the lower bound of  $S_I$  can be any number greater than zero. Practically, a project would have a ratio greater than 1 to be included in the set of projects under review. The use of cumulative ratios to compute  $S_I$  makes

index values approaching 1 very unlikely. The minimum value of  $S_1$  shown in Table 5-1 was that obtained for the sample set of Appendix A.

5.5.4. Status Factor. The status factor ( $S$ ) is designed to accommodate the performance history of ongoing projects. It seems reasonable to propose that a project with a proven history of good performance should receive extra credit over a new project whose performance can only be promised. Similarly, a project with poor performance should be penalized. The score of a new project should be unaffected by  $S$ . The method proposed for doing this is to have  $S$  assume the following values as a multiplier in the scoring algorithm.

$$\begin{aligned} 0 \leq S \leq 2, & \text{ for ongoing projects} \\ S = 1, & \text{ for new projects.} \end{aligned}$$

## 6.0. CONCLUSIONS AND RECOMMENDATIONS

### 6.1. Conclusions.

6.1.1. Planning Phase. The planning process for Army MANTECH projects is highly structured and follows procedures and requirements established by DOD and DMT. The three principal activities of the planning phase are development of the 5-year program plan, the budget review, and the apportionment review. Although the planning process is highly structured and uniform for all major subordinate commands, it undergoes frequent review and is modified from time to time to improve the efficacy of the process.

6.1.2. MANTECH Program. The conduct of the MANTECH Program is a continuous, iterative process in which the review and evaluation of proposed projects is only a part. The principal steps are

- Monitor and evaluate current methods of commodity manufacturing;
- Determine priority needs for improving current methods;
- Communicate those needs to all parties involved;
- Identify candidate projects to provide the priority needs;
- Screen, evaluate, and rank projects;
- Select and conduct projects to demonstrate ability to meet needs;
- Disseminate results to manufacturing community to promote technology development;
- Implement proven concept in mass production; and
- Assess success of implementation and determine new priority needs.

The only unique aspect of the TACOM MANTACH Program, as with any SUBMACOM, is its product line. Therefore, the establishment of needs related to tactical and combat vehicles is important.

6.1.3. Evaluation Methods. A large number of evaluation parameters (~25) were obtained from a review of regulations and from a survey of DOD commands. It was concluded that there is a great degree of commonality among many of these parameters because they are different expressions of identical concerns. None of the commands contacted during this study use a numerical weighting of evaluation parameters to define priorities.

The majority of commands interviewed have developed a standard operating procedure (SOP) or internal regulations to guide the evaluation process; TACOM does not, however, use an SOP or guidelines. All commands, with the exception of TACOM, also use a peer review group to select and rank projects. The use of peer group review and the adherence to standard procedures cannot by themselves guarantee objectivity in the evaluation process. However, they are valuable tools that provide a framework for a more objective evaluation, and the TACOM process could be enhanced if it employed these features.

All commands estimate economic benefit, which is not a primary factor in ranking projects.

Because the majority of projects are multiyear, the evaluation methodology must consider their progress and status.

The evaluation methodology must be sufficiently flexible to accommodate projects that vary widely in technical scope. For example, MACI and MMT projects are different project classes.

Improved productivity and cost savings are the predominant benefits associated with projects. Almost all MANTECH projects provide improvements that can be related to cost savings, although some are second-order effects and not readily defined. A review of the estimates of costs and benefits contained in P-16 forms submitted by TACOM reveal a wide variation in the depth of economic analysis. As expected, estimates depend on how well the project is technically defined. It also was concluded that the estimates of implementation costs are frequently limited to conduct of the MANTECH project; the true cost of implementing a proven MANTECH concept in mass production may be more than the estimated implementation cost.

## 6.2. Recommendations.

The following recommendations are presented for consideration by TACOM in its effort to improve the evaluation and ranking of MANTECH projects.

6.2.1. Prioritization Methodology. The prioritization methodology should be considered as part of a continuing MANTECH process and not a discrete activity. This effort should include, for example, year-long work in the following areas.

- Identify and rank priority needs in the manufacture of TACOM commodities through continual liaison and personal contact with program management offices and others directly responsible for commodity manufacture. Priority lists of major MANTECH needs should be developed and maintained by the TACOM MANTECH office.
- Communicate those needs to all parties to promote the creation of new ideas and projects that may meet those needs.
- Awareness of the progress achieved and problem areas of all ongoing MANTECH projects.
- Promote results of successful projects to aid the likelihood of implementation:
  - Establish and maintain user contacts to cultivate project sponsors,
  - Keep sponsors informed of project progress,
  - Track implementation results and benefits, and
  - Evaluate results or problems to identify new project needs.

Solicitation and development of new ideas should be considered as a year-round activity, including discussion with all parties involved in commodity manufacture.

6.2.2. Standard Operating Procedure and Guideline. An SOP and internal guideline for developing and submitting MANTECH proposals should be developed. In particular, TACOM should establish a review group for the evaluation and ranking of projects. The selection of its members and the procedures it follows should be planned carefully. An SOP would provide an outline for the review and evaluation process; it should include procedures for:

- Screening projects and rejecting or modifying, as required;
- Identifying evaluator requirements and selecting and procuring members of the review group.
- Appointing a chairperson of the review group from the MANTECH organization and establishing an agenda.
- Obtaining consensus on points of fact regarding each proposal at first meeting (subsequently, scoring each proposal using the algorithm below and ranking projects accordingly);
- Modifying ranking process, if required, by open comment and discussions; and
- Maintaining a permanent record of results of each meeting.

A set of guidelines, to be included with a formal request for proposals that defines the information required and its format, should include

- Priority listing of TACOM needs;
- Screening criteria to be used, with clarifications of the MANTECH Program, as appropriate;
- DARCOM guidelines and P-16 forms;
- Internal TACOM guidelines, as appropriate; and
- Evaluation parameters to be used in project review.

Guidelines to insure consistency in the development of estimates of project benefits and costs should be developed. For example, consideration should be given to the following:

- Assume 10-year production runs (or procurement, in the case of MACI projects) beginning 1 year after completion of the MANTECH demonstration;
- Establish uniform, yearly inflation and discount rates to be used in estimates of benefits and costs; and
- Emphasize the need to estimate and include production line implementation costs (i.e., post-MANTECH), including operation and maintenance.

The following algorithm should be used to compute scores to obtain an initial ranking of projects.

$$\text{Score} = \left[ \frac{100(R_n + B_n)}{n} \right] \left[ P_s \times P_I \right] \left[ S_I \right] \left[ S \right]$$

where

- $n$  = priority of need met (1.0 to  $N$ )
- $R_n$  = relevance of project to need (0.2 to 1.0)
- $B_n$  = secondary benefit (0 to 0.5)
- $P_s$  = likelihood of success (0.2 to 0.8)
- $P_I$  = likelihood of implementation (0.2 to 0.8)
- $S_I$  = economic index ( $>0$  to 10)
- $S$  = project status, for ongoing projects (0 to 2)  
for new projects (1)

The economic index ( $S_I$ ) is normalized to mitigate the large excursions observed in estimates of benefits and costs. It is determined as follows:

$$S_I = 10 \left\{ \frac{\frac{\sum_i (B_i)}{1}}{\frac{\sum_i (C_i)}{1}} \right\} \frac{1}{(B_i/C_i)_{\max}}$$

## LIST OF ACRONYMS AND ABBREVIATIONS

AFWAL	Air Force Wright Aeronautical Laboratories
AR	Army Regulation
A/R	approval pending rewrite
AMMRC	Army Materials and Mechanics Research Center
D/R	defer for rewrite
D/TR	defer for technical reevaluation
DA	U.S. Department of the Army
DESCOM	Depot Systems Command
DMT	Directorate of Manufacturing Technology
DOD	U.S. Department of Defense
HQDA	Headquarters, Department of the Army
HQ-DARCOM	Headquarters, U.S. Army Material Development and Readiness Command
IBEA	Industrial Base Engineering Activity
MACI	Military Adaptation of Commercial Items
MANTECH	Manufacturing Technology
MMT	Manufacturing Methods and Technology
MTAG	Manufacturing Technology Advisory Group
NAC	Needs Assessment Committee
PBSP	Production Base Support Program
PEM	Production Engineering Measures
PM	Project Manager
RAM-D	reliability, availability, maintainability, durability
R&D	research and development
RFP	Request for Proposal
ROI	return on investment
SOP	Standard Operating Procedure
SUBMACOM	Major Subordinate Command
TACOM	U.S. Army Tank-Automotive Command



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APPENDIX A.

RANKING OF CUMULATIVE BENEFIT TO COST RATIOS

There are a variety of classic economic methodologies and measures of merit suitable for project prioritization. The benefit (B) to cost (C) ratio, or savings to investment ratio, was selected as the preferred measure of merit for MANTECH projects. This ratio is defined as the net economic benefit received during the life cycle of the new process or technique when applied in mass production (or during use of an adopted commercial item) divided by the total MANTECH project cost plus its implementation, or start-up, cost. In computing this ratio, all benefits and costs are converted to present values by use of inflation and discount factors as stipulated by Army Regulations.

AR 11-28, Economic Analysis and Program Evaluation for Resource Management, provides general support for this selection and guidance in the area of developing an incremental merit for evaluating and ranking alternative projects. Specifically, support for use of an incremental approach to project evaluation is found in Section 1-8(2), page 1-4 of AR 11-28.

...[The purpose of the economic analysis is to] rank these alternatives, based on their benefit to cost relationship. Economic Analysis is designed to assist the manager in identifying the most cost effective alternative available to the Army for accomplishing a goal.

With respect to ranking of alternatives and selection of a preferred alternative

[In situations where costs and benefits of alternatives are unequal], the analysis should compare incremental benefits with incremental costs. Thus, the preferred alternative would be the one with the largest rate of effectiveness to cost. [Section 2-3(f)(3)(c), pg. 2-6]

AR 11-28 is fairly specific in terms of the most desirable manner in which the question of prioritization should be addressed. From a purely economic perspective, the task of prioritizing MANTECH projects becomes one of optimization based on some measure of cost effectiveness per dollar spent.

An approach that can be applied to all projects for which an economic analysis has been accomplished is the incremental benefit/cost ratio analysis, whose purpose is to identify the most cost-effective means of investing limited resources. In the context of economic analysis of the TACOM MANTECH Program, projects should be arrayed to reflect the most cost-effective ordering of MANTECH investment alternatives. Alternative approaches were explored in attempting to determine a consistent methodology that would yield such an array.

A sample of MANTECH projects with estimates of discounted program benefits and costs was extracted from the FY 1984 P-16 forms (Part II). This sample consisted of 10 projects of varying cost, ranging from approximately \$200,000 to slightly over \$2.8 million, with individual benefit/cost ratios ranging from 49.52 to 1.18. The objective was to develop a consistent approach to arraying the projects so as to maximize the cost effectiveness per dollar invested. The simplest approach is to rank each project on the basis of descending benefit/cost ratio, invest in the project with the highest benefit/cost ratio first, and then estimate the cumulative benefit/cost ratio by adding the benefit and cost of each successive project. Let  $i$  represent the  $i$ th project in a set of projects. The cumulative, incremental benefit to cost ratio (savings to investment ratio) is then generated for the  $i$ th project by

$$\frac{\sum_{j=1}^i (B_j)}{\sum_{j=1}^i (C_j)}$$

Table A-1 presents the results of using this alternative.

While straightforward, this approach will not consistently yield the highest values of incrementation. Theoretically, it is possible to enter projects in order of descending B/C ratios and obtain the highest incremental B/C ratio. However, as shown below, it is not an optimal approach; an alternative approach yields higher incremental B/C values. The following approach was taken using the same data set.

The project with the highest individual benefit/cost ratio is identified first, representing the most effective initial investment when funding a single project. The project of second rank is then determined by computing  $(B_1+B_i)/(C_1+C_i)$  in sequence for each of the remaining  $(n-1)$  projects and selecting the project that yields the highest incremental cumulative benefit/cost ratio.

In the data set used for evaluation purposes, the second most incrementally cost-effective project was identified as project No. 7, with an incremental benefit/cost ratio of 45.35. Adding project No. 7 to project No. 1 results in the greatest addition to total benefits at the lowest cost. Of specific interest is that the benefit/cost ratio of project No. 7 is 2.87, substantially lower than the second highest overall project benefit/cost ratio in the data sample (i.e.,  $B_2/C_2=13.09$ ). Similarly, the third-ranked project is selected from the remaining  $(n-2)$  projects by choosing the project that maximizes  $(B_1+B_7+B_i)/(C_1+C_7+C_i)$ . The ranking of each remaining project is determined in similar fashion; the results are listed in Table A-2.



Table A-1. Ranking in Order of Benefit-to-Cost Ratio

Project Number (ranking) (i)	Benefit (B <sub>i</sub> )	Cost (C <sub>i</sub> )	Individual Benefit/Cost Ratio (B <sub>i</sub> /C <sub>i</sub> )	Incremental Cumulative Benefit/Cost Ratio*	
				$\sum_{i=1}^i (B_i)$	$\sum_{i=1}^i (C_i)$
1	101.02	2.04	49.52		49.52
2	4.32	0.33	13.09		44.45
3	1.84	0.46	4.05		37.87
4	2.64	0.66	4.00		31.47
5	3.68	0.93	3.97		25.68
6	2.31	0.70	3.30		22.62
7	0.56	0.20	2.87		21.87
8	7.90	2.82	2.80		15.27
9	0.54	0.23	2.33		14.91
10	0.28	0.23	1.18		14.55

\*Based on decreasing value of individual benefit/cost ratio.

Table A-2. Comparison of Project Rankings

Project Number (ranking) (i)	Individual Benefit/ Cost Ratio (B <sub>i</sub> /C <sub>i</sub> )	Incremental* Cumulative Benefit/ Cost Ratio		Project Number (ranking) (i)	Individual Benefit/ Cost Ratio (B <sub>i</sub> /C <sub>i</sub> )	Incremental** Cumulative Benefit/ Cost Ratio	
		i $\Sigma(B_i)/$ 1	i $\Sigma(C_i)$			i $\Sigma(B_i)/$ 1	i $\Sigma(C_i)$
1	49.52	49.52		1	49.52	49.52	
2	13.09	44.45		7	2.87	45.35	
3	4.05	37.87		9	2.33	41.34	
4	4.00	31.47		2	13.09	38.01	
5	3.97	25.68		10	1.18	35.20	
6	3.30	22.62		3	4.05	31.09	
7	2.87	21.87		4	4.00	26.78	
8	2.80	15.27		6	3.30	23.39	
9	2.33	14.91		5	3.97	20.27	
10	1.18	14.55		8	2.80	14.55	

\*Based on decreasing value of individual benefit/cost ratio.

\*\*Based on decreasing value of the ratio of cumulative benefits and costs.

Table A-2 depicts the difference in project rankings resulting from an analysis of cumulative incremental benefit/cost ratios that is based on descending individual project B/C ratios versus the project rankings that result from use of cumulative incremental B/C ratios. When funds are constrained, the use of an incremental benefit/cost ratio is more consistent with AR 11-28 in terms of generating the highest economic return per dollar invested. Theoretically, a better ranking can be obtained by considering all possible combination of projects, and computer optimization programs are available to do this. However, such complexity is not warranted in this instance because economic benefit is not the only evaluation parameter and the technical parameters affect the overall rank of each project. The simplified optimization scheme demonstrates that substantial improvements in economic benefit can be identified that are adequate for assigning the weight of economic benefit to project rank. It should be noted that this simplified approach also involves a considerable number of comparisons to be made when the number of projects approaches 40, as can be the case at TACOM. With 40 projects, approximately 700 comparisons are involved. However, the Lotus 1-2-3 computer program, which was designed for this kind of calculation, can provide a spread sheet like that shown in Table A-3.

To make the economic component of the ranking algorithm consistent in scale with other elements of the algorithm, it is recommended that the incremental cumulative benefit/cost ratios be normalized by dividing them by the maximum individual benefit-to-cost ratio of the set. In addition, as shown below, the multiplier 10 reduces the prevalence of small decimals.

$$S_I = 10 \frac{\sum_{i=1}^i (B_i) / \sum_{i=1}^i (C_i)}{(B_i/C_i)_{\max}}$$

The calculation of the economic index  $S_I$  for the sample set yields the indexes listed below.

<u>Project Number</u>	<u><math>S_I</math></u>	<u>Project Number</u>	<u><math>S_I</math></u>
1	10.0	3	6.29
7	9.18	4	5.42
9	8.37	6	4.73
2	7.62	5	4.24
10	7.12	8	2.94

If the suitable software is not available to conduct the simplified optimization method recommended herein, the economic index can be determined by reverting to the simpler alternate ranking by individual benefit/cost ratio. In this case, the sample set has the following indexes.

<u>Project Number</u>	<u>S<sub>I</sub></u>	<u>Project Number</u>	<u>S<sub>I</sub></u>
1	10.0	6	4.57
2	8.96	7	4.42
3	7.65	8	3.09
4	6.36	9	3.01
5	5.19	10	2.94

Table A-3. Cumulative Incremental Benefit/Cost Ratio

Project Number	Project B/C Ratio	A	B	C	D	E	F	G	H	I
1	49.52									
7	2.88	45.35								
9	2.33	44.74	41.34							
2	13.09	44.45	41.27	38.01						
10	1.18	44.57	41.26	37.94	35.20					
3	4.05	41.23	38.44	35.59	33.31	31.09				
4	4.00	38.41	36.00	33.52	31.57	29.65	26.78			
6	3.29	37.67	35.35	32.96	31.08	29.22	26.48	23.39		
5	3.97	35.28	33.27	31.18	29.57	27.90	25.44	22.66	20.27	
8	2.80	22.41	21.65	20.81	20.36	19.59	18.47	17.10	15.84	14.55

Column	Includes Projects
A	1, i
B	1, 7, i
C	1, 7, 9, i
D	1, 7, 9, 2, i
E	1, 7, 9, 2, 10, i
F	1, 7, 9, 2, 10, 3, i
G	1, 7, 9, 2, 10, 3, 4, i
H	1, 7, 9, 2, 10, 3, 4, 6, i
I	1, 7, 9, 2, 10, 3, 4, 6, 5, 8

APPENDIX B.

GLOSSARY OF EVALUATION PARAMETERS

## B-1.0. NEED CATEGORY

For the need category, the evaluation parameters are synonymous with the parameters that typify the need because it is expected that the proposed MANTECH improvement project will be in direct response to the need.

### B-1.1. Increased Productivity.

Increased productivity is a measurable increase in the number of units produced in a given time without increasing production capacity. It can be achieved by means that directly increase the rate of production or by improving the quality of production that indirectly increases the rate. Advancement in the state of the art is subsumed within this parameter. Such increases should result in benefits that can be quantified in the economic analysis.

B-1.1.1. Increased Production Rate. An increased production rate is a measurable increase in the number of units produced in a given time by improvements in processes or techniques, by increases in efficiency, or through equipment changes that result in mechanization or automation. Although increased production is normally a laudible goal, the question, "Why?" has to be asked. In general, it can be for one of two reasons. Either the current rate is inadequate to meet requirements reflected in the current Mission Statement, Army Materiel Plan, or other appropriate Army document, or costs can be reduced by producing more units (if required) in a given time or the same number of units in less time. Which of these is important should be addressed in the establishment of need.

B-1.1.2. Improved Quality. Quality is the umbrella of all the other "ilities." It is difficult to envision something that is highly reliable, very durable, and easy to maintain, and yet is of poor quality. Also, if it has all these good attributes, it most certainly should enhance availability. "Improved quality" is often cited as the justification for a MANTECH project; however, the reference is usually to the quality of the end item being produced and not the quality of the manufacturing change. This approach is not entirely valid, and the following distinctions should be made. Quality must be "designed into" the hardware, whether it be the end item being produced or the process, technique, or equipment that produces it. There is no incentive, or real payoff, in improving quality beyond that required by the design. What is required is to "insure" that the designed quality is being met and maintained.

The primary focus in evaluating MANTECH projects should be on the quality of the manufacturing process, technique, or equipment. Test

and inspection of this improvement change\* can only demonstrate the degree to which quality is being maintained. It would seem quite natural that a poor quality manufacturing method is likely to produce a poor quality end item. Therefore, in the event one starts to see a degradation in the quality of the end item, it may be wise for the hardware design engineer to get together with the production design engineer and ascertain the true cause. This degradation, in turn, may dictate a new MANTECH need; the solution for which will again be evaluated according to the other "ilities" mentioned above.

A particular MANTECH project under evaluation may be the direct result of a need to insure quality of the end item. More sophisticated machinery, tighter controls, and increased automation are examples of changes that can increase precision and guarantee reproducibility or repeatability, thereby increasing yield. Quite often, however, these projects are promoted under the military Quality Assurance Program, which is a separate DOD activity.

Improved quality of manufacturing will result in less downtime or higher yields, benefits that can be quantified in the economic analysis.

B-1.1.2.1. Increased Reliability. Reliability is often reflected in terms that relate to the performance of the end item being produced, and not the manner by which it is produced. Producing in a manner that causes poor quality or high rejection rates does not affect the reliability of the end item, which, if built to design, would have the same inherent reliability; it just makes the required quality more difficult, time consuming, and costly to achieve. For MANTECH projects, however, the measure of reliability should be restricted to the manufacturing process, technique, or equipment; mechanisms that are not large repetitive volume buys and that are not themselves subjected to lot sampling or reliability testing, although some of the piece parts that go into these mechanisms may be so tested.

By definition, if the manufacturing technology project is to be an improvement, it cannot degrade reliability, and the degree of improvement is very difficult to measure. Therefore, the best measure of a "more reliable" manufacturing process, technique, or equipment would be an increase in production rate resulting from either less

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\*There also are end item peculiar "test and inspection" MANTECH projects that should not be confused with the test and inspection of the new manufacturing change. MANTECH test and inspection projects represent an improvement in things such as better screening, easier testing, faster screening or testing. Some of these can directly enhance the quality of the end item being produced by better rejection of poorly manufactured components.



downtime (as mechanism is repaired) or lower rejection rates (higher yield). A new mechanism that just produces at a faster rate would not represent an increase in reliability.

B-1.1.2.2. Maintainability. By definition, any improvement in a manufacturing process, technique, or piece of equipment is not an improvement if it degrades maintainability. Again, one has to be careful to distinguish between maintenance of the production-oriented improvement, as opposed to maintenance of the end item being produced. For MANTECH projects, the emphasis should be on maintenance of the production change.\* The design of the end item being produced, as opposed to the manner in which it is manufactured, normally affects the maintenance of the end item.

Measures of the maintainability of the production change are reflected in attributes that contribute to ease of repair, extent to which it must be replaced, and longevity (mean time to repair or replace). These are "life cycle" questions that apply to the manufacturing change and not the end product. Any possible negative impact on maintainability of the end item would be grounds for canceling the project and, it is hoped, these relationships would have been defined in the R&D or feasibility stage prior to becoming a MANTECH project.

These measures should be reflected in the economic analysis as they are related directly to manufacturing operation and maintenance (O&M) costs and the costs of varying the production time and rate.

B-1.1.2.3. Availability. As with maintainability, an improved manufacturing process, technique, or equipment is no real improvement if it is not available. A highly precise and repeatable piece of machinery that is unavailable increases downtime. The emphasis for MANTECH projects should be on the availability of the improvement, which is largely a function of its reliability and maintainability, or mean time between failure (MTBF) and mean time to repair (MTTR).

Also, a case where there just "are not enough" good and improved pieces of manufacturing equipment (i.e., unavailability) is an insufficient reason to promote it as a MANTECH project and, therefore, should not be considered. The acquisition of additional normal manufacturing capability to expand the industrial base or to meet surge and mobilization requirements should be provided by normal production appropriation funds.

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\*There are, however, some MANTECH projects that can enhance maintenance of the end item. For example, certain improved "test and evaluation" methods or equipment may be better able to predict failures; thereby, extending the useful life of the end item while allowing for corrective action before the failure actually takes place.

B-1.1.2.4. Durability. Again, as with other ilities, one should assess the durability of the improved manufacturing process, technique, or equipment, not the durability of the end item being produced.\* "Will the new mold, die, etc., hold up as well as the item it is replacing, or will the automated handling equipment wear out before its manual counterpart?"

#### B-1.2. Conserve Critical and Costly Materials.

The need to conserve critical materials, or resources, can, by itself, be a justification for a MANTECH project. A MANTECH project is a solution to such a need and it may embody the substitution of new or different materials, which may dictate a change in the manufacturing process or just a change in the manufacturing process that eliminates waste. In certain instances, the improvement change may be so demonstrative (e.g., near net shape versus complex machining from scratch) that quantified values may be generated for the economic analysis. However, it may quite often be a second-order effect and difficult to quantify.

#### B-1.3. Improve Safety.

Compliance with Occupational, Safety, and Health Administration (OSHA) regulations is a normal TACOM requirement, and manufacturing changes to accomplish this are normally funded with OMA funds or PA funds. However, these are instances where the application of MANTECH resources would be appropriate. For example, regulatory compliance may be satisfied through the use of protective clothing that may be awkward or bulky, restricting operations or limiting the amount of time that the worker can spend on the associated operation without accepting undue risks. A manufacturing improvement, through automation, may actually take the worker out of the loop, thereby, improving the safety of the operation as well as improving the production rate. Although a case can be made that this improvement should result in a cost savings (e.g., fewer lost workdays, more units produced, lower overhead), it is a second-order effect and difficult to quantify in the economic analysis.

#### B-1.4. Conserve Energy.

The need to conserve energy is an important Army program given special consideration by the authority of the "Army Energy Program," AR 11-27. Energy savings can be realized through new breakthroughs in manufacturing improvement that would, therefore, make them candidates for MANTECH projects. In most instances, however, energy conservation

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\*There are, however, some MANTECH projects that can enhance durability of the end item. For example, a change to a less-corrosive material, or a new rubber compound that makes the end item more durable, may require a new manufacturing method to produce it.

projects are of such a general nature that they are more appropriately funded with OMA funds.

Given other higher priority needs of TACOM, the opportunity for a project to be supported solely on the basis of energy conservation is quite small. However, all MANTECH projects present the opportunity for conserving energy and the projected savings in cost (which is the best measure of the benefit, as opposed to Btu's or gallons of oil) can readily be developed and should be incorporated into the economic analysis.

#### B-1.5. Reduce Environmental Impact.

Compliance with Environmental Protection Agency regulations, like safety, is a normal TACOM requirement, and manufacturing changes to accomplish this are normally funded with OMA or program funds. Given other higher priority needs of TACOM, it is unlikely that a MANTECH project would be approved solely on the basis of this parameter. The benefits of controlling pollution are hard to quantify as they are a function of the type of pollutant, the geographic area of the source, the amount of pollutant being discharged, and the environmental pathways for its impact. Often the incorporation of pollution reduction equipment will cost more, therefore, a savings to investment ratio calculation would not be a reason to promote the project.

#### B-1.6. Reduce Costs.

Cost reduction, a somewhat self-explanatory parameter, is mentioned here separately as it may be synonymous with a need statement. Normally, all cost reductions will fall under the economic analysis. The challenge to reduce costs may stem from a rather broad need related to a complete commodity item (e.g., an Industrial Productivity Improvement (IPI)), where many opportunities may be proposed, to a narrow need related to a specific operation related to a commodity subsystem or component.

Cost savings can result from changes in many things, such as facility layout and size; modernized, mechanized, or automated equipment; new process or technique; improved factory flow; personnel reductions and changes in skill levels; new procedures; reorganization; and reduced overhead.

#### B-2.0. RISK CATEGORY

##### B-2.1. Likelihood of Success.

Proposed projects should present practicable alternatives to manufacturing processes, techniques, or equipment. The proposed project must have had its feasibility demonstrated (e.g., laboratory or bench scale) prior to undertaking it as a MANTECH project. However, there are still problems that may be encountered as scale-up

to production is not always as straightforward as one would like it to be. Yet, the project must demonstrate that the concept is suitable to direct transition to the mass-production manufacturing floor.

#### B-2.2. Likelihood of Implementation.

A committed sponsor who is willing to implement the proposed MANTECH project is a very important asset to the proposal. There can, however, be problems with implementation even if the PM strongly supports a MANTECH project when it is proposed. After the project is completed and ready to be implemented, the management of the program office may have changed and there is a chance that the new PM may not be willing to accept the risk associated with "doing things differently than in the past." This situation requires placing continuing emphasis on implementation and coordination with the program office.

There also is the chance that the improvement would be implemented without the benefit of MANTECH. In many instances, the length of the budget cycle (2 to 3 years), the length of the demonstration project (up to 3 years), and the lead time to get the proven demonstration implemented (1 year estimated) are such that events may overtake the idea and it may become a reality without MANTECH. This possibility raises the question, "What is the likelihood of the project being implemented without Army sponsorship?" A question appropriate to initial screening of MANTECH proposals.

Also, consideration should be given to the "ease" of implementation. Would implementing the project cause a major disruption in the current manufacturing process? Will the production line have to be shut down, and, if so, for how long? Will the facility require major structural modification or renovation? How many procedures or shop instructions must be modified?



APPENDIX C.

INTERIM PROGRESS REPORT FOR  
MANTECH PRIORITIZATION METHODOLOGY PROGRAM

## 1.0 INTRODUCTION

This report presents the results obtained to date on the Manufacturing Technology (MANTECH) Prioritization Methodology Program. This program consists of a study to develop a method, or procedure, for evaluating and selecting candidate MANTECH projects at the U.S. Army Tank-Automotive Command (TACOM). Selected programs are subsequently submitted to the Industrial Base Engineering Activity (IBEA), Rock Island, Illinois, and the Materials and Mechanics Research Center (AMMRC), Watertown, Massachusetts, for review, and to the U.S. Army Material Development and Readiness Command (DARCOM) for approval. MANTECH projects to be evaluated include those of Manufacturing Methods and Technology (MMT) and Military Adaptation of Commercial Items (MACI).

Section 2.0 of this report summarizes the work of Task I of the study, which is to survey the Department of Defense (DOD) commands involved in the evaluation of MANTECH project types, to review their procedures for review and evaluation, and to assess the applicability of these review procedures to TACOM needs.

Section 3.0 presents the results of an analysis of the TACOM FY 1985 programs submitted to IBEA and AMMRC for review, and their ranking by each. An analysis of the review comments on these submittals (i.e., P-16 forms) given by IBEA and AMMRC also is included.

Section 4.0 addresses the accomplishments of the work on Task III of the study, which is to identify the manufacturing and operational parameters to be used for the evaluation of candidate MANTECH proposals. The significant parameters are selected, defined, and discussed in terms of utility to the evaluation.

Section 5.0 presents a discussion of methods of cost analysis, as required by paragraph C.3.1.2 of Task III. A comparison of the classic methods is given that identifies the savings-to-investment ratio as the most appropriate.

The work remaining to complete the study consists of the completion of Tasks III and IV. The principal subtask to be completed in Task III is that of determining the method of relating evaluation parameters to cost factors. In Task IV, the development of the procedures for engineering review and analysis, with emphasis on the organization and operations of the peer review group, and the determination of the manner in which risk can be assessed is to be completed.

## 2.0 REVIEW OF EXISTING METHODOLOGIES

A survey was taken of the procedures used by other military commands to evaluate, rank, and select MANTECH projects for submittal to higher authority for approval. The purpose of the survey was to evaluate their applicability to TACOM for the evaluation of its MANTECH

projects. Points of contact within MANTECH organizations of the Army, Navy, and Air Force were identified, and interviews were conducted. Figure 1 is representative of the steps followed by the major system commands in processing and obtaining approval of MANTECH proposals. It is used as a frame of reference for summarizing the findings of the survey.

## 2.1 Army Commands

The formal process of initiating MANTECH projects is nearly identical among the Army commands visited because they all must follow requirements instituted by the Directorate of Manufacturing Technology (DMT) at Headquarters DARCOM, as promulgated by IBEA. Differences lie in the details of their internal review methods, the evaluation parameters selected as paramount, and the screening criteria used. None of these commands used a numerical algorithm to evaluate projects. Although a few had supported studies to devise mathematical methods for decisionmaking, none were ever implemented. A significant number follow the ranking scheme devised by AMRRC (Ref. 1) but none use it in arriving at their final internal ranking of projects (see Section 3.0).

### 2.1.1 Armament, Munitions, and Chemical Command (AMCCOM), Rock Island, Illinois

#### 2.1.1.1 Munitions

##### 2.1.1.1.1 Origin of Projects

As with most commands, the needs perceived by the engineers and managers are the prime source for new ideas that form the basis for MANTECH projects. Those closest to existing manufacturing processes, techniques, and equipment also are closest to industry counterparts and are most familiar with the state of the art. They are in a logical position to recommend candidate projects by virtue of their day-to-day activities. Although ideas for improving manufacturing techniques can and do occur at any time, their transformation to formal proposals follow the timely process of responding to the January call for proposals issued by DARCOM, and responses are in accord with established guidelines. For example, the Production Base Modernization Agency in Dover, New Jersey, conducts a fall guidance conference for the Armament, Munition and Chemical Command that is followed by preliminary submittals to working-level meetings before guidelines are formulated for the preparation of the P-16 forms.

The use of a cost driver analysis, or "top down" study, can be used to originate projects; but it is not standard procedure. The purpose is to determine the sources of the largest costs in the production of an item, or group of items in a given facility. Presumably, the sum of these large cost elements for a production activity largely determine, or drive, the total procurement cost and offer the greatest potential



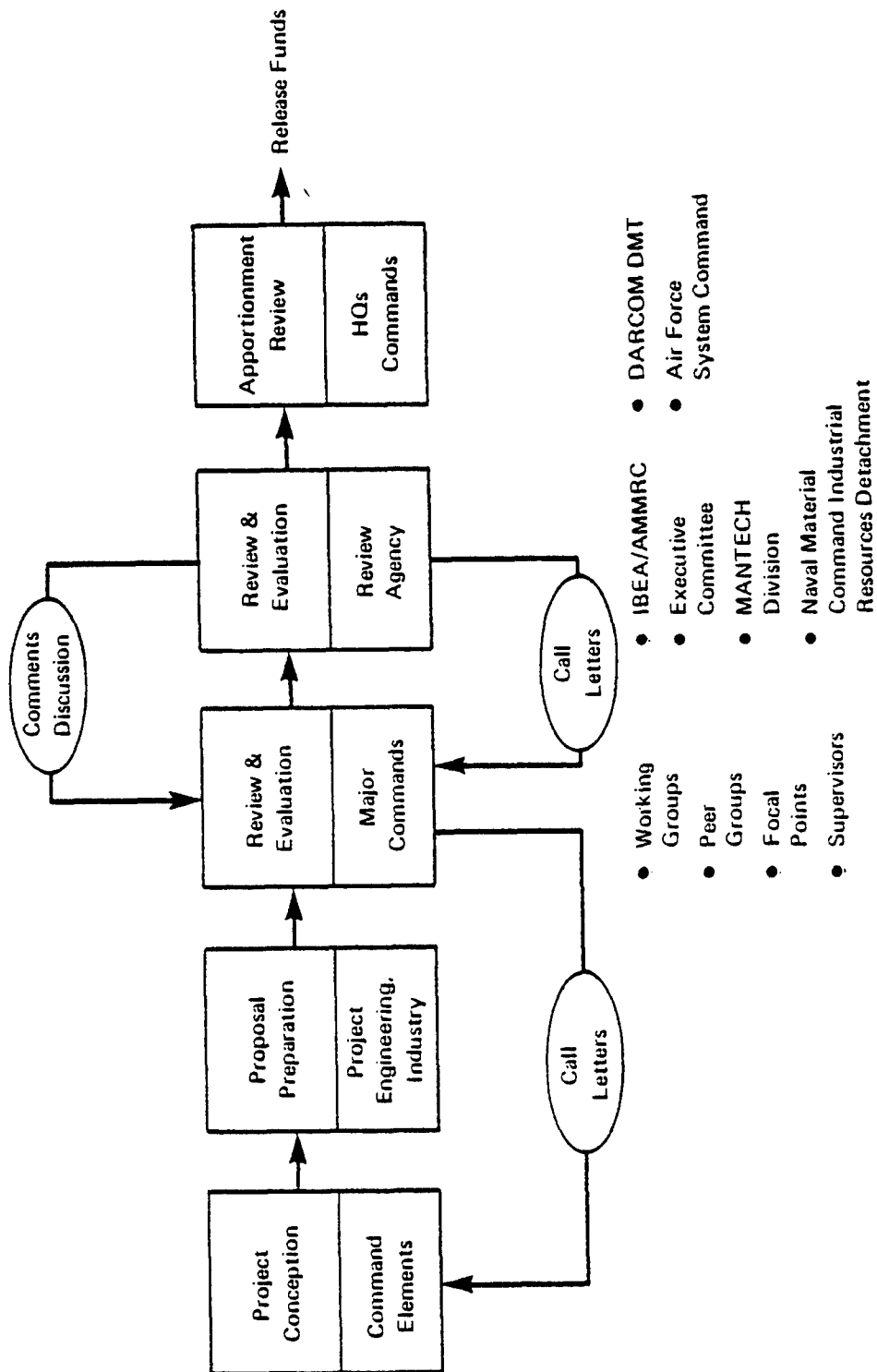


Figure 1. MANTECH Project Selection

for improvement and savings. To identify the large cost elements, the production activity is separated into major categories, such as parts or material processing, fabrication, assembly, and burden. Each of these is further broken down into subelements as fine as the cost accounting system will allow for the allocation of costs by labor, materials, equipment, etc.; hence, the term "top down" study. In this manner, large cost elements are highlighted according to manufacturing activity, each of which can then be analyzed for potential improvement. Concern was expressed that emphasis on this approach overstates the needs of a single-weapon system at the expense of projects with the potential for generic application.

A number of unsolicited proposals are submitted that can appear at any point in the chain of command where the contractor perceives a receptive audience. The number of unsolicited proposals processed varies between subcommands, but is probably influenced by whether they include government owned government operated (GOGO), government owned contractor operated (GOCO), or contractor owned contractor operated (COCO) facilities. However, they are handled in the same manner as all other proposals. There is always the critical project, mandated by higher command, that can bypass some of the steps of Figure 1.

In summary, projects originate at the working level, primarily from engineers active in manufacturing. A minor portion of the projects originate as unsolicited proposals. Guidelines are established in the fall of each year to insure that candidate projects will meet the munition needs of AMCCOM.

#### 2.1.1.1.2 Review and Evaluation

Interdisciplinary peer review is the dominant method used for evaluating and selecting projects. This is true not only for AMCCOM but also for every command visited. Technical experts consisting of project engineers, laboratory, and arsenal personnel are selected for the review panel. Working-group meetings are convened to select and rank projects within a given discipline or product and are conducted informally by the members to reach a consensus. This process is followed by an Executive Review Board, which evaluates all projects. The Executive Review Board meetings include representatives of IBEA and AMMRC for coordination. In both cases, qualitative methods are used to make decisions. These decisions are reached by considering the following factors:

- Screening Criteria
  - Satisfy safety and pollution control regulations (Occupational Safety and Health Administration (OSHA) and Environmental Protection Agency (EPA))
  - Return on investment (ROI) must be greater than 1.5
- Evaluation Parameters
  - Projected improvements in safety and pollution abatement

- Support of major modification and expansion programs
- For new programs, satisfy 5-year defense plan (FYDP)
- Support mobilization needs
- Uniqueness of technology proposed
- Interest of command

The munitions area of AMCCOM is unique in the degree of concern expressed for safety and pollution. Obviously, considering their product, safety is important. Also, because they have extensive manufacturing responsibilities as a single weapons manager (i.e., sole source), they are saddled with the disposal of large amounts of toxic waste, including NO<sub>x</sub>, H<sub>2</sub>NO<sub>3</sub>, heavy metal salts, and solid wastes. Hence, these areas receive high priority in the evaluation.

The prioritization process is qualitative, and no numerical scores are used. The munitions group noted the difficulty in trying to make the process completely objective. However, they believe their method of evaluation is quite valid, and any added complexities to increase objectivity are not worthwhile.

#### 2.1.1.1.3 Project Award

Once the P-16 proposal passes the evaluation of the Executive Review Board, is ranked high enough to be included within the funding guidelines, and is modified as required for the DMT review at DARCOM, preplanning is initiated in terms of the preparations of the statement of work structure and specification of deliverables. The goal is to hold the period between release of funds and initiation of contract to about 6 months. Once a project is under way, the Production Base Modernization Agency at Dover, New Jersey, holds quarterly reviews on the status and progress achieved.

#### 2.1.1.2 Weapons

The weapons group at AMCCOM follows the procedure described above, except for the following characteristics.

- Screening Criteria
  - Improve quality assurance
  - Satisfy safety and pollution control regulations
  - Be aligned with the Critical Items List of the Army
- Evaluation Parameters
  - Support mobilization requirements
  - Be aligned with the FYDP
  - Have the greatest economic benefits

In comparison, the Weapons Group of AMCCOM used a simpler selection process in terms of the number of evaluation parameters, and the fact that the proposal must observe the Critical Items List. The Weapons Group, perhaps as a result of its second evaluation parameter, claimed

a high correlation between the FYDP and projects funded. It was the only command interviewed that reported a high correlation.

## 2.1.2 Aviation Systems Command (AVSCOM), St. Louis, Missouri

### 2.1.2.1 Origin of Projects

As with AMCCOM, the prime source of projects at AVSCOM are the technical staff at the working level. Preparation of the development of ideas and preplanning begins in October in anticipation of the call letter in January. AVSCOM sends call letters to Langley Air Force Base for programs related to structures, to Fort Eustis for applied technology, to the Propulsion Laboratories in Cleveland, and to AMMRC. It was noted that AVSCOM considers many of the acronyms applied to production engineering programs, such as technology modernization (TECHMOD), IPI, IMIP, to be basically all the same type of work. In this regard, AR 700-90 and AR 70-1 (Refs. 2 and 3) are being revised, but there is disagreement on how it should be modified.

### 2.1.2.2 Review and Evaluation

The review group at AVSCOM consists primarily of members of the Production Technology Branch of AVSCOM, with occasional assistance from specialists from the laboratories. There is no formal written procedure, although Battelle Laboratories conducted a study (Ref. 4) for AVSCOM in 1976 on the subject of MANTECH Program guidance. The main emphasis of this study is the identification of promising projects for the formulation of a realistic FYDP, although it did include recommendations for scoring and weighing evaluation parameters.

- Screening Criteria
  - Satisfy regulatory requirements contained in AR 700-90 (Ref. 2)
- Evaluation Parameters
  - Probability of implementation
  - Savings to investment ratio (>3:1)
  - Potential for generic application
  - Degree of technical risk

Much of the review panel's work centers on the questions of proven feasibility and if generic application can be achieved. The latter issue is resolved by determining where and how other applications of projects could be obtained, and viewing projects pointed to a specific weapons system (as most are) as a demonstration program for the concept used in each project. In general, ongoing programs receive the highest priority.

Concern also was expressed that cost savings must not take precedence over technical advances; improvement in manufacturing performance

should be of equal importance. AVSCOM also confirmed a lack of correlation between the FYDP and the projects that are funded.

#### 2.1.2.3 Project Award

Most of the AVSCOM projects that are funded are initiated through competitive procurements with industry because it is quicker than sole-source procurements. Requests for Proposal (RFP), proposal evaluations, and contract awards are done at the laboratory level where the work will be conducted. Each project also is monitored by one of the project engineers of the Production Technology Branch. In addition to the progress reports required by regulations, in-house reviews are held to insure progress and control costs. Although the probability of implementing projects is of top priority during evaluation, checks on the implementation of successful projects are few. Of 124 projects conducted between 1967 and 1979, four were tracked to calculate savings on performance.

#### 2.1.3 Army Missile Command (MICOM), Huntsville, Alabama

##### 2.1.3.1 Origin of Projects

Throughout the year, conferences are held in-house and with other government agencies to determine perceived needs that should be supported. This process is a principal source of ideas for MANTECH projects. Early in the year, a call letter asking for projects is sent by the MMT Division to all MICOM divisions. The Technical Integration Office develops a list of command priorities, or major thrust areas, that is provided as guidance to the MMT Division. Thus, the projects that are contained in the Part I P-16 form represent these command priorities. The number of ideas for projects that are received directly from industry are relatively small. The major source is through the interaction of project engineers with the relevant industry.

##### 2.1.3.2 Review and Evaluation

Expert committees are formed within the MMT Division to review these projects. The initial selection of projects for the Part I P-16 form is a screening to make certain that each meets some of the needs of the command priorities. There is no numerical ranking done at this time; rather, these Part I forms are sent to IBEA for review. At this point, IBEA may question the feasibility of projects but normally reviews them from the standpoint of which funds are used in allocations, and checking for duplication and general housekeeping. Following this review, they are returned to MICOM and to the project engineer who originated the proposal. Subsequently, IBEA travels to MICOM for a one-on-one meeting with each project engineer. It is here that the final ranking is performed. There are no written procedures on the ranking process; it is accomplished through the use of qualitative considerations rather than quantitative factors.

- Screening Criteria
  - Is not research and development (R&D) work
  - Meets a command need
  - Is a clear proposal, i.e., follows AR 700-90 (Ref. 2)
  - Has potential for generic application
- Evaluation Parameters
  - Supports end-item producibility
  - Reduces production lead times
  - Reduces production costs
  - Increases productivity
  - Improves process reliability
  - Conserves energy and scarce resources
  - Insures economic availability of end item
  - Reduces safety hazards and pollution

There is no minimum ROI required, although this analysis is done by the project engineer and follows AR 11-28A (Ref. 5). In general, there is little confidence in ROI projections. The difficulty with these projections is that the amount of savings accrued depends on the number of people who will pick up the concept and use it in manufacturing, which is almost impossible to determine. However, a cost driver analysis is performed for all MICOM programs. Critical needs might override cost considerations and could result in the selection of a project that has a negative ROI.

Auburn University conducted a study (Ref. 6) for MICOM on the use of automated selection or prioritization of projects. The final report of this study consists of a complex, theoretical analysis of utility and decisionmaking theory, and includes a recipe that permits one to score projects according to the degree that the project meets six objectives (see Section 3.0). This method has not been implemented.

The MMT Division is of the opinion that emphasis should be given to projects that are applicable to the concept and advanced development phase of acquisition, rather than the engineering development or production phase. This is believed necessary to support production schedules while coping with the time it takes to process proposals and get projects under way, which is difficult because regulations prohibit research, development, testing, and evaluation (RDT&E) funding for MANTECH projects. Another difficulty is the requirement to evaluate each project at the end of the first year to estimate benefits to cost savings. It is believed a longer period should be used for this evaluation.

#### 2.1.3.3 Project Award

All projects are conducted by contractors. These procurements may be competitive or sole source; the decision is left to the discretion of the Procurement Division. The MMT of MICOM has a very thorough system of promoting and tracking implementation results after project

completion. A member of the MMT staff is given responsibility for technology transfer. Video tapes of the processes developed by successful projects are available for loan to help sell the ideas (catalogues of these are sent to prospective users) and seminars and demonstrations also are held. Less success has been obtained in estimating savings accrued through implementation. In many cases, the contractor is loath to provide this information for business reasons. In some cases, the contractor is reluctant to admit that a particular technique has been incorporated in its plant. Nevertheless, MICOM appears to have an excellent program for evaluating implementation effects, and has managed to estimate cost savings for a substantial number of projects.

#### 2.1.4 Industrial Base Engineering Activity (IBEA), Rock Island, Illinois

##### 2.1.4.1 Origin of Projects

IBEA (and AMMRC) support DMT at Headquarters DARCOM in the screening and selection of projects for funding. As such, they are not involved directly with the source of projects, other than in the issuance of call letters to the major system commands in January of each year and in the preparation and dissemination of the FYDPs. Their principal role is to insure that the proposals brought forward meet MANTECH objectives and that they are responsive to guidelines established by DARCOM.

In terms of the phases of the acquisition cycle (concept phase, demonstration and validation phase, full-scale engineering development phase, and production and deployment phase), MANTECH projects appear to occur wherever the need arises, except that they are not used to produce more than one-of-a-kind, i.e., they may only demonstrate mass production capability as a pilot run. However, IBEA views MANTECH projects as being in one of three phases designated as development, production, or maintenance, with the development phase embodying the first three phases of the acquisition cycle. MACI projects are considered part of the late development and early production phase, while MMT projects are initiated primarily in the production phase.

##### 2.1.4.2 Review and Evaluation

IBEA reviews all projects forwarded by the major systems commands in support of DMT. IBEA does not rank projects but does score them according to the following:

- Screening Criteria
  - Follow guidelines as expressed by the regulations on submittal

- Evaluation Parameters
  - Need
  - Probability of success
  - Potential benefits

The scores given each parameter are multiplied together to obtain a product of ratings in a range of 0 to 64. AMMRC also scores projects according to the following scheme, based on the MANTECH objectives cited in AR 700-90 (Ref. 2):

<u>Evaluation Parameters</u>	<u>Weight</u>
Pollution abatement	10
Production safety	10
Rate of ROI	8.
Support of production requirements	8
Uniqueness to Department of Defense (DOD) production	5
Critical materials savings	3

The scores of each parameter (from -10 to +10) are multiplied by the respective weighting factor and summed. The sum is then multiplied with the scores (1 to 3) given for probability of success and for probability of implementation. The final score could range from -1320 (not likely) to 1320.

After reviewing proposals, IBEA discusses each one with originators at each major system command, recommending changes as required before submittal to DMT for final review. At the DMT review with the systems commands, representatives of IBEA (and AMMRC) are present, not as advocates but as consultants and coordinators.

#### 2.1.4.3 Project Award

After projects are funded, IBEA supports DMT in the review and tracking of project performance through status reports, final reports, and effectiveness reports submitted by project engineers. IBEA summarizes these results by preparing consolidated reports for DMT review.

### 2.2 Air Force Commands

#### 2.2.1 Air Force Wright Aeronautical Laboratories (AFWAL), Dayton, Ohio

The AFWAL MANTECH Division, Materials Laboratory, is the lead agency of the Air Force for MANTECH and is analogous to the Army DMT. AFWAL is responsible for the planning, evaluation, and selection of projects to be implemented by the Air Force. While there is no formal documentation of the procedures followed by the MANTECH Division, they are very similar to those of the Army.



#### 2.2.1.1 Origin of Projects

Projects are solicited from the various product divisions of the Air Force by the MANTECH Division. The product divisions, in turn, routinely solicit industry for project ideas related to critical areas. Industry briefings are held in each focal point area to inform them of needs and opportunities.

#### 2.2.1.2 Review and Evaluation

When received, projects are collated into groups of similar objectives, called focal areas or focal point efforts; these correspond to critical areas of technology necessary to Air Force systems development. Development of focal point efforts is a year-round effort by the MANTECH Division, with inputs from the product divisions, and corresponds to what are called thrust areas in some of the Army commands. Because projects are processed explicitly according to which focal point they support, great emphasis is given to the criteria that projects meet an identified need of the Air Force. Current focal points include:

- Nonmetals
- Metals
- Electronics
- Thermal Protection
- Nondestructive Inspection
- Propulsion
- Computer-Aided Manufacture (CAM)

An Executive Committee, consisting of Division Chiefs, the Chief of Operations, and the Chief of Plans for the Materials Laboratory, appoint focal point leaders who, in turn, appoint members to form a peer review panel to review, evaluate, and prioritize candidate projects. A representative of the MANTECH Division is a member of each focal point panel. As with other commands contacted in this survey, the focal point panels depend on qualitative, rather than quantitative, factors in establishing priorities. Estimates of ROI are largely ignored in this process. Of greater importance is the likelihood of the project improving system performance, or the "ilities", i.e., reliability, availability, maintainability, durability (RAM-D). Screening factors related to safety, energy, or pollution are not involved.

The findings of each focal point panel are submitted to the Executive Committee for review and then to the MANTECH Division, which prepares a final report for submittal to the Air Force Systems Command (AFSC), Deputy for Contracting and Manufacturing. In preparing this report, which includes all Air Force MANTECH projects, some restructuring of priorities may occur in order to meet the budget limitations of each product division. In this sense, projects do not compete across product divisions in this process, although this may occur in the focal point evaluation process.

#### 2.2.1.3 Project Award

The procurement cycle is approximately 6 months, with a total time of approximately 8 months between proposal submittal and start of contract. Approximately 80 percent of the funded projects are solicited from industry; only 5 percent represent unsolicited proposals. Approximately 70 percent represent ongoing efforts. Work is just beginning on evaluation of the success rate, implementation rate, and cost benefits of funded projects.

#### 2.2.2 Ballistic Missile Organization (BMO), San Bernardino, California

BMO is not involved directly in MANTECH projects because they are handled by the MANTECH Division at AFWAL. BMO may provide project ideas as a result of solicitation from the MANTECH Division but are not otherwise active in that area. The work at BMO is concerned solely with TECHMOD. The objective of TECHMOD is to "accelerate the implementation of advanced manufacturing technology through the coupling of contractual incentives with technology development" (Ref. 7).

##### 2.2.2.1 Origin of Projects

BMO does not currently have any TECHMOD projects but is awaiting proposals from three contractors. The method for initiating projects is to originate plans in-house, brief relevant contractors on these plans, and solicit proposals. BMO refers to three phases in TECHMOD projects.

Phase I: Top down studies and analyses of what needs to be done and projected benefits.

Phase II: Prototype demonstration of Phase I concepts and compare results with predictions.

Phase III: Apply successful prototypes to a manufacturing environment.

It is planned for the first phase to be funded by the contractor, with incentives to proceed to the second and third phases provided by BMO.

##### 2.2.2.2 Review and Evaluation

BMO will rely on the support of the technical expertise resident in the various product managers' offices for proposal evaluations. Because of the recent birth of this effort, project selection is implicit in the in-house process of origination. However, the following evaluation parameters are used in the approval of contractor efforts.

- Support a specific application or need
- Criticality of need being supported
- Reduce costs
- Timeliness

There is no threshold of economic benefits, nor are there guidelines on how to estimate benefits. However, they must be reasonable and verifiable.

#### 2.2.2.3 Project Award

Competitive proposals are considered impractical. The reasoning is that one contractor will not accept the risk of an approach or application proven by another contractor unless funded to demonstrate it again; this is one of the difficulties in achieving technology transfer.

### 2.2.3 Space Division (SD), El Segundo, California

#### 2.2.3.1 Origin of Projects

A call letter for projects is issued from AFSC to program offices in the first quarter of each calendar year. The program office develops projects both internally and from inputs obtained from contractors, i.e., similar to the methods used by Army commands. Proposals are prepared using a simplified version of the P-16 form.

#### 2.2.3.2 Review and Evaluation

Projects are presented to a senior MANTECH review group that subsequently ranks the proposals before forwarding them to AFSC (i.e., AFWAL).

- Screening Criterion
  - No R&D
  - No duplication of effort
  - Generic
- Evaluation Parameters
  - Criticality of project
  - Project funding level required
  - Projected improvements in system efficiency and life

Each project is rated by all members of the review group, and a consensus on the prioritization of projects is reached. This process is informal, and no quantitative methods are used in deriving priorities. There are no written guidelines or descriptions of these procedures. Highly detailed economic analyses are not conducted.

#### 2.2.3.3 Project Awards

Most MANTECH SD projects last 2 to 3 years. No details were available on whether effectiveness studies of these projects are conducted by SD or the proportion of competitive to sole-source awards.

#### 2.3 Naval Material Command Industrial Resources Detachment (NMCIRD), Philadelphia, Pennsylvania

NMCIRD provides technical support to Naval Material (NAVMAT) on MANTECH projects and has responsibilities similar to those of IBEA in support of DMT. NMCIRD is organized along the lines of the MTAG subcommittees, with an engineer heading each of the six disciplines. NMCIRD may request assistance from technical staff members of other system commands when required. Because the first MANTECH projects were begun in 1977, the MANTECH Program at NMCIRD is just beginning to mature.

##### 2.3.1 Origin of Projects

The prime source of projects are those offered by contractors working on Navy programs. In the future, NMCIRD plans to emphasize larger programs for major weapons systems through the use of "top down" studies for identification of projects. Cost driver analysis is considered a valuable asset in this identification.

##### 2.3.2 Review and Evaluation

NMCIRD does not participate in the evaluation of projects prior to receiving them for review. Each command has received budget appropriations from NMCIRD, and the command submittals generally match their budgets. Thus, there is really no competition among the commands for project funds. NMCIRD does reject proposals, which is based solely on the project's lack of compliance with NAVMAT instructions (NAVMATINST 4800.36D) (Ref. 8).

The screening criteria in these instructions are:

- Satisfying a Navy requirement to provide increased productivity or process applicability;
- Solving problem solutions through the use of new, improved, or more economical manufacturing processes, methods, techniques, or equipment;
- Incorporating state-of-the-art capability;
- Not duplicating effort;
- Being beyond the normal risk of industry;

- Having a reasonable payback time; and
- No R&D effort.

NMCIRD does not use a numerical ranking scheme in assessing its evaluation, and the economic assessment is somewhat limited in that it is based on a payback time of 5 years, beginning with the initial release of funds. Given that most projects take 3 years to be demonstrated plus another year before they are implemented, one certainly cannot have "life cycle" costs taken into consideration with only 1 year of production considered.

NMCIRD does not consider qualitative or subjective benefits, such as RAM-D. It is assumed that the proposed projects do not violate or adversely impact RAM-D; the extent to which they are improved is secondary to the main objective of the program. Likewise, no specific attention is paid to pollution abatement, safety, or energy conservation. OSHA and EPA regulations govern these parameters and they are, therefore, not of themselves justification.

In line with the above, NMCIRD agrees that any improvement in reliability should be restricted to the manufacturing process, technique, or equipment and not to an improvement in the reliability of the end item. The latter may be a result of a design change or a change in requirements, albeit a new requirement may dictate a change in manufacturing. Therefore, mean time between failure (MTBF) or mean time to repair (MTTR) are not worthy of consideration unless there is some way to prove that the "manufacturing process" alone contributed to these benefits.

### 2.3.3 Project Award

Overall, approximately 25 percent of NMCIRD projects are implemented.

## 2.4 Summary of Findings

Results of the survey detailed in the above discussion are summarized in Table 1. The following characteristics, which typify the processing and evaluation of MANTECH projects by the commands visited, can be deduced from Table 1.

### 2.4.1 Origin of Projects

- All depend on ideas originated by working-level engineers for their source of projects. The interaction of these personnel with their industrial colleagues represents an important contribution to this process. Approximately a third of the commands surveyed have established guidelines that identify critical needs or missions that should receive priority support from MANTECH.

Table 1. Observations to Date

Command	Origin of Projects	Use of Cost Driver Analysis	Development of Major Thrust Areas	Use of Standard Operating Procedure	Peer Review Evaluation	Use of Quantitative Evaluation Parameter (weighting/ranking)	Emphasis on ROI	Comparison of Implemented to Predicted
AMCCOM Munitions	Bottom-up*	?	PDMA Dover*	No	Yes	No	Yes	No
Weapons	Bottom-up*	No	Yes	Yes	Yes	No	Yes	No
IBEA	N/A**	No	N/A	Yes	N/A	Tried (not too enthusiastic)	No	Yes
AVSCOM	Bottom-up	No formal fashion	Mission & Functions AVSCOM 10-1	Yes	Yes	No	No	No (stress implementation)
MICOM	Bottom-up***	Yes	Yes	Yes	Yes	No	No	Yes
ASD	From product division	Yes	Yes	Yes	Yes	No	No	No
SD	Bottom-up	Yes	Yes (assumed from ASD)	Yes	Yes	No	No	Limited
NMCIRD	Bottom-up	No	Yes (must meet Navy need)	Yes	Quasi	No	Yes	No

\*Fall Guidance Conference.

\*\*N/A = Not applicable.

\*\*\*Year-round, in-house conference.

- A few use cost driver analyses but the emphasis of their use appears to be for planning top down studies of large production facilities.
- The majority of commands provide guidelines to their subcommands, which define new mission requirements or critical problem areas that need emphasis in allocating resources or should receive priority in the planning and selection of projects. Some commands conduct conferences and seminars to publicize these needs to industry as well as government staff.

#### 2.4.2 Review and Evaluation

The use of peer review groups is the core of the evaluation, and is common to all commands interviewed. Further, the manner in which those groups are organized and operated is quite similar. Review group members are selected on the basis of expertise in the disciplines required for conduct of the proposed projects. A chairman is usually appointed from the staff of the MANTECH unit of the command, although in some cases an executive review board is convened to review the findings of the peer review group. All such groups are conducted informally, at which time a consensus is reached on the value of each project and those to be selected for approval. The consensus is based on subjective evaluations referenced to evaluation parameters established for each command, discussion, and persuasion. None of the commands has written guidelines or a description of these proceedings, although AVSCOM has published a regulation (70-6) that defines policy, responsibilities, and the eligibility criteria for projects.

The set of screening criteria and evaluation parameters selected by each review group varies widely and runs the gamut from the specific (e.g., the savings to investment ratio shall exceed a given number) to the intangible (e.g., improve the military industrial base). Nevertheless, each set contains elements that are common to others, and most appear to be derived from published regulations and instructions. Table 2 lists those criteria and parameters obtained from the survey. In addition, the screening criteria and evaluation parameters contained in regulations, instructions, and two publications on evaluation methods are included for comparison (Ref. 4 and 6).

It is apparent from Table 2 that regulations, as a group, prescribe more screening factors than the commands follow in their evaluations (33 versus 25). The criterion of generic application represents the greatest difference; of the commands surveyed, only two listed this as a requirement. However, it is used as an evaluation parameter by three of the commands surveyed. In one sense, emphasis on projects for single products is to be expected from the way in which most projects are originated. The concerns of engineers are likely to be

Table 2. Criteria and Parameters

Evaluation Parameter	Army					Air Force		Navy	
	AMCCOM	AVSCOM	MICOM	IBEA	AMMRC	BMO(1)	SD	NMCIRO	
Probability of Implementation Project Endorsement		x x		x					
Criticality of Project			x			x	x		
Conserve Critical Materials	x		x		x				
Reduce Costs Life Cycle ROI	x		x	x		x			
SIR		3							
Other		x	(2)						
Technical Risk		x		x					x
Beyond Normal Risk of Industry									x
Generic Application		x							
Establish Production Process					x				x
New		x							x
Improved									x
Less Costly									x
Insure Producibility			x						
Reduce Lead Time			x						
Develop Multiple Source									
Improve Industry Base	x								
Follow-On Project		x							
Status									
Results									
Remaining Budget									

- (1) TECHMOD only.  
(2) Cost driver analysis.



Table 2. Criteria and Parameters (continued)

Evaluation Parameter	Army				Air Force		Navy
	AMCCOM	AVSCOM	MICOM	IBEA	AMWRC	BMO(1)	SD
Meets Need Unique to Military Requirements Mission Thrust Area			x	x		x	
Timely						x	
Improve Energy Safety Pollution			x				
Improve Ilities End Item Manufacturing Process		x			x x		x

Table 2. Criteria and Parameters (continued)

Evaluation Parameter	Regulations					Publications			
	DOD	DARCOM Call Letter	AF REG 800-33	AR 700-90	DOD INSTR 4200.15	DARCOM Handbook 706-1.1-80	Battelle MANTECH Guidance	Auburn University	Donnelly DDR&E
Probability of Implementation	x	x							x
Project Endorsement	x								x
Criticality of Project						x		x	
Conserve Critical Materials	x	x	x	x					
Reduce Costs	x			x	x	x	x	x	x
Life Cycle									
ROI		x	x						
SIR					(1)				
Other									
Technical Risk	x	x							x
Beyond Normal Risk of Industry									x
Generic Application	x						x	x	x
Establish Production Process	x	x			x	x			
New							x		
Improved				x	x				
Less Costly				x					
Insure Producibility			x	x	x	x			
Reduce Lead Time			x	x	x				
Develop Multiple Source	x			x					
Improve Industry Base			x						

(1) Identify and quantify.

Table 2. Criteria and Parameters (continued)

Evaluation Parameter	Regulations*				Publications*			
	DARCOM Call Letter	AF REG 800-33	AR 700-90	DOD INSTR 4200.15	DARCOM Handbook 706-1.1-80	Battelle MANTECH Guidance	Auburn University	Donnelly DDR&E
Follow-On Project Status								
Results Remaining Budget								
Meets Need Unique to Military Requirements	x			x				x
Mission Thrust Area		x				x	x	
Timely	x		x	x		x	x	
Improve Energy Safety Pollution	x	x		x	x			
Improve Ilities End Item	x	x		x		x		
Manufacturing Process						x		

\*Sources:

AF 800-33, "Acquisition Management, Manufacturing Technology Program," Headquarters, Department of the Air Force, Washington, D.C., April 15, 1982.  
 AR 700-90, "Logistics, Army Industrial Preparedness Program," Headquarters, Department of the Army, April 15, 1982.  
 DOD Instruction 4200.15, "Manufacturing Technology Program," Department of Defense, July 14, 1972.  
 DARCOM Handbook, 706-1.1-80, "Manufacturing Technology Handbook, Change 1," U.S. Army Management Training Activity, April 1981.  
 Henning, H.J., and T.G. Byrer, "Army and Aviation MANTECH Program Guidance," Battelle Columbus Laboratories for Aviation Systems Command, AVSCOM Report No. DRSAV-76-30, June 1976.  
 White, Charles, "Project Selection Criteria," Department of Industrial Engineering, Auburn University, June 1982.  
 Donnelly, "Proceedings of the 13th Annual MANTACH Conference, MIAG 81," Department of Defense Research and Engineering, December 3, 1982.

Table 2. Criteria and Parameters (continued)

Screening Criteria	AMCCOM	AVSCOM	MICOM	IBEA	BMO	SD	NMCIRD	DOD	AF REG 800-33	AR 700-90	DOD INSTR 4200.15	DARCOM Handbook 706-1.1-80	Donnelly DDR&E
Conserve Energy	{1}	{1}		{1}									
Enhance Safety	{1}	{1}		{1}									
Abate Pollution	{1}	{1}		{1}									
Generic Application			x		x		x(3)	x	x	x(2)	x		
Reduce Costs	ROI 1.5	x					x		x	x	x	x	x
Proven Feasibility	x	x					x		x	x	x	x	
Satisfy Needs	x	x							x				
Establish Better Process								x(4)			x	x	
New													
Improved										x			
Less Costly										x			
Clear Proposal		x											
Follows AR 700-90			x							PA/OMA			
Funding Source													
Does Not													
Change End Item													
Design								x			x		
Test End Item								x			x		
Procure Capital													
Equipment								x		x	x		
Produce Handbook								x			x		
Duplicate													
Previous Work								x	x		x	x	
Include R&D		x					x						
FYDP	(1)		x				x			x			

(1) Satisfy regulations, (2) Whenever possible, (3) 5-yr payback, (4) Includes inspection systems, (5) Use cost driver studies

Sources:

AF 800-33, "Acquisition Management, Manufacturing Technology Program," Headquarters, Department of the Air Force, Washington, D.C., April 15, 1982.  
 AR 700-90, "Logistics, Army Industrial Preparedness Program," Headquarters, Department of the Army, April 15, 1982.  
 DOD Instruction 4200.15, "Manufacturing Technology Program," Department of Defense, July 14, 1972.  
 DARCOM Handbook, 706-1.1-80, "Manufacturing Technology Handbook, Change 1," U.S. Army Management Training Activity, April 1981.  
 Donnelly, "Proceedings of the 13th Annual MANTACH Conference, MTAG 81," Department of Defense Research and Engineering, December 3, 1982.

dominated by problems they identify with the manufacture of a particular system they are involved with or are responsible for. In most cases, they do not have the opportunity or time to stand back and assess the potential of their concept to other applications. Overall, the most frequently cited screening criteria are that the feasibility of the project is proved and that it does not duplicate previous work. The most frequently cited evaluation parameters are that the project is timely (i.e., for application) and that it conserves critical materials. Direct questions regarding the need to support more than a single weapons system elicited ambiguous responses. There seems to be hope that, although the proposed project is directed to a single end item, as the project develops it will prove beneficial to the production of other end items.

None of these review groups uses a numerical method to rank the projects under review. Three studies (Ref. 4, 6, 10) were conducted to develop such methods; however, none has ever been implemented. The fact that those projects to be compared represent such a wide diversity of kinds of work and technical disciplines undoubtedly contributes to the difficulty in finding a suitable alternative to the current method. A few participants are uncomfortable with the subjective basis of the review group decisions, but most are experienced in the project areas under review and are qualified in their fields. It is believed by most of those interviewed that the review groups can exercise informed judgment that provides a high confidence in the results and that the encumbrance of a higher degree of sophistication or quantification is not warranted.

All Army and Navy commands require an economic analysis to be performed in accordance with AR 11-28 (Ref. 5) and NAVMATINST 4800.36D (Ref. 8), respectively, but no comparable directives exist for the Air Force. NMCIRD does emphasize cost driver analyses as a tool for planning projects, as does IBEA. However, the results of the economic analyses do not appear to be of great importance during review and evaluation. The review groups do not normally question the validity of cost savings estimated by the proposer and possibly assume that a successful project will be cost effective. Many of those interviewed expressed skepticism regarding the projection of benefits, or financial savings, that would accrue from implementation of the project because they believe it is extremely difficult to assess the extent of technology transfer to be obtained. A few mentioned that a project fulfilling a critical need would be approved with a savings to investment ratio of less than one.

#### 2.4.3 Project Award

After approval and release of funds, projects undergo the normal procurement cycle of other programs that requires 6 to 9 months. There is no consistency among commands regarding the ratio of competitive to sole-source awards. Some leave the decision up to procurement; others appear divided between favoring competitive or

sole-source bids. After award, a project engineer is assigned to monitor each project; this person is usually a staff member of the command's MANTECH group, although not always. In addition, a few commands hold quarterly reviews of progress over and above the status reports required by regulations.

The Army has the most formalized procedure for tracking the success of projects by means of the annual Effectiveness Reports required by IBEA for all projects that have been completed. Also, MICOM has supported innovative methods to promote technology transfer from its projects. The Air Force is just beginning efforts to track the successes of its projects. Efforts by the Navy in this area are not known.

## 2.5 Conclusions From Findings

The procedures used by the three services in selecting MANTECH projects are quite similar. All depend on inputs from contractors in deriving new projects, and the use of peer review groups in evaluation is universal. The screening criteria and evaluation parameters used by the various commands have many common elements, although each is a unique set. In general, no more than eight factors are considered during evaluation. None of these commands has ever attempted to use algorithms or quantitative measures of utility for ranking or selecting projects. The Army has the most thorough procedures and detailed guidelines of the services for processing and managing MANTECH projects, possibly because it has the largest budget and most experience in MANTECH.

The applicability of these procedures to TACOM for selecting projects is still under analysis; however, the following tentative conclusions are offered:

- The only unique aspect of the TACOM process, as with any command, is its product line, i.e., combat and tactical vehicles. Therefore, the use of guidelines that define the major thrust areas and critical needs for the manufacture of these products is recommended.
- Obviously, a peer review group must be used at some level and in some fashion to rank and select proposals for recommendation to IBEA. The diversity of technologies implicit in the projects submitted requires a matrix support to attain the necessary broad range of expertise. The operation of these groups in the commands surveyed has been characterized as "informal" and reaching decisions by means of "informed judgment." This process needs a better definition to be of use, and alternative methods in the selection and management of the review group are being explored. It should be unique to the extent that it meets the needs and resources of the TACOM organization.

- The screening criteria and evaluation parameters used by those commands surveyed, and as extracted from regulations and other publications, are so numerous that they cover nearly every utility aspect one could conceive of for any project. Therefore, it is doubtful that factors identified for the evaluations of TACOM would not be those listed in Table 2, or at least subsumed under one of the entries.

The identification of criteria and parameters is nearly complete. Screening criteria must be in accord with Army regulations and guidelines. The evaluation parameters should have the following characteristics:

- Be applicable to a broad range of projects covering processes, techniques, and equipment for both MMT and MACI;
- Be specific and capable of being defined without ambiguity or the requirement for lengthy contingency clauses;
- Be mutually exclusive, which is related to the previous characteristic; and
- Where possible, be related directly to cost benefits or be quantifiable.

The selected list should be made as small as possible in order to make the methodology more manageable. This aspect is discussed further in Section 4.0.

The feasibility of developing a practical algorithm for reaching decisions "by the numbers" is still under consideration but the experience of others who have attempted this does not make this approach appear promising. Nevertheless, it might be useful in arriving at a first cut to segregate candidates in groups prior to the final ranking.

### 3.0 RESULTS OF P-16 EXHIBIT ANALYSIS

To become familiar with the kinds of projects to be evaluated and ranked, MMT and MACI P-16 exhibits were reviewed. Particular attention was given to FY 1985, where each project was tabulated according to approximately 12 major headings (e.g., cost, ROI, major thrust, MTAG category, TACOM and IBEA/AMMRC priority). The results of this analysis were inconclusive in terms of identifying any particular evaluation parameters other than the indication that a high degree of emphasis was placed on need or problem solving, which was to be expected. Also, there was no positive correlation between the IBEA/AMMRC priority and the ultimate priority assigned. For example, code 31 projects (tracked combat vehicles) submitted for FY 1985 consisted of 37 projects; of these, 32 were MMT projects and 5 were MACI projects. Slightly more than 50 percent of the MMT projects were

for improving a current production process or for increasing productivity; approximately 25 percent were for developing a new production process, and another 25 percent were for developing new inspection or test procedures. Attempts to relate the IBEA, AMMRC, or TACOM rankings for these projects resulted in scatter diagrams with no evident correlation. The approval percentage in each of these groups obtained from IBEA or AMMRC varied from 50 percent to 0; it is not known how these projects will fare in the apportionment review. Just under half of the proposed projects are ongoing efforts.

While efforts to find patterns or correlations related to cost benefits, priority rankings, evaluation scores, or the IBEA/AMMRC recommendations were not successful, a review of the evaluation comments of IBEA and AMMRC revealed a set of shortcomings most frequently cited, the distribution of which is shown in Figure 2. The abscissa of Figure 2 indicates the issue, or area of concern, to which each set of comments is addressed. Each number refers to a paragraph of the P-16 form; other captions refer to a screening factor or guidelines on the preparation of the P-16 form. Figure 3 is a sample P-16 form, Part I.

The fact that some submittals did not meet the definition of MMT effort as given in the regulations was the most frequent (38) comment by far. The most common basis for this judgment was that the proposal was a facilities project. Other reasons were that it was an industrial productivity improvement or product improvement program effort, or that the proposed technique had been applied successfully or was state of the art.

The second highest categories concerned item 14, "Key Milestone Dates," and the environmental statement of Inclosure 1 (20 each). Apparently, the title of item 14 was assumed by originators to refer to milestones within the MMT project rather than the project implementation milestones; perhaps the title should be changed. The reasons for citing Inclosure 1 were that it was omitted, was not signed off by an environmental officer, or did not include a Record of Environmental Consideration. Other significant issues included:

- Item 10a: Quantifiable Benefits (17)--In 13 cases, none were given; in 4 cases, there was no basis given for the estimate.
- Item 8: Solution (16)--The most common reason for this comment was a lack of detail, followed by the observation that the solution did not address the problem or a manufacturing activity.



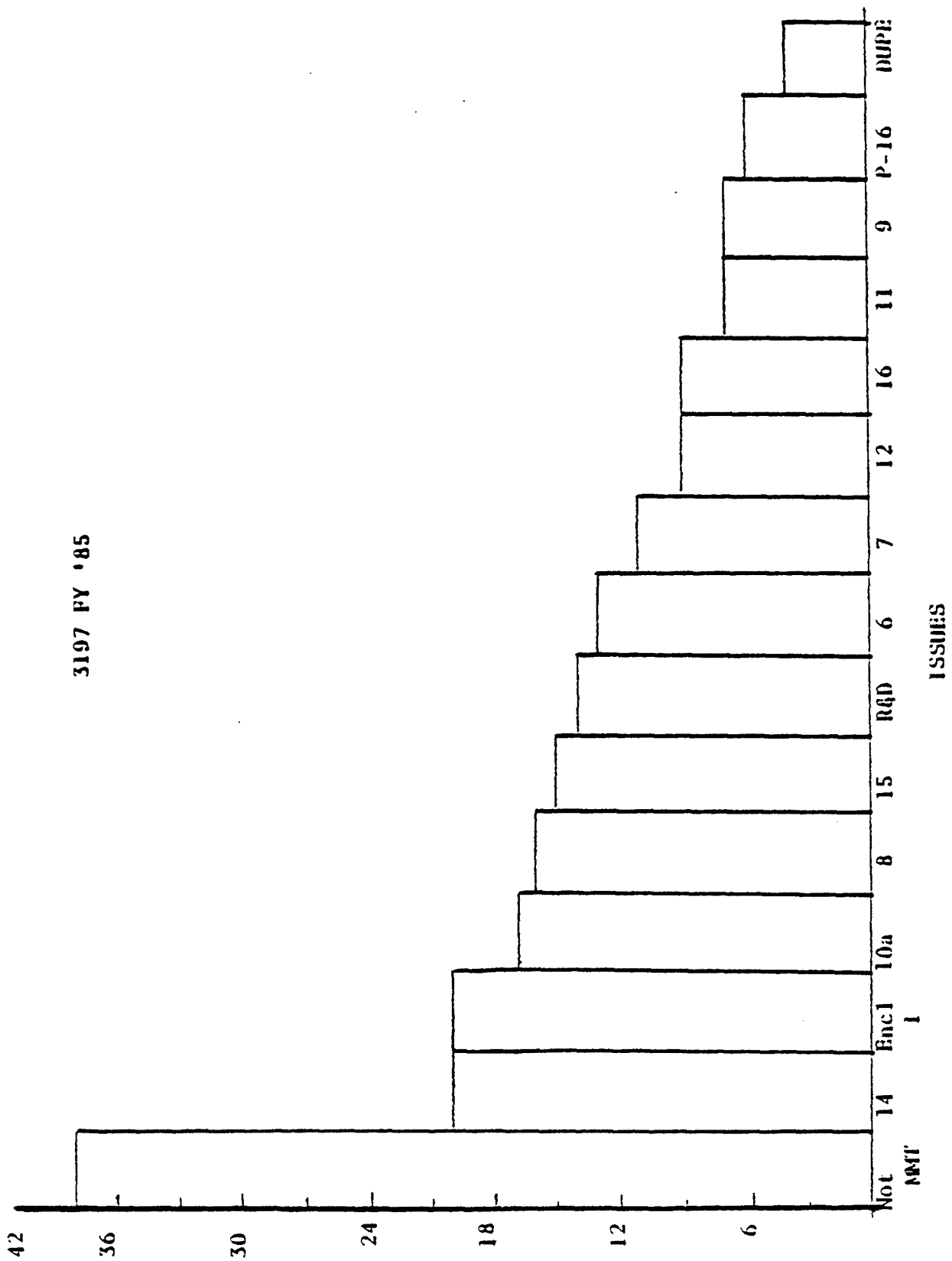


Figure 2. Distribution of Comments

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EXHIBIT P-16 (PART I)  
Production Engineering Measures  
(PEM) Project  
RCS DRCMT-835

Date:

- 
1. Project Number:
  2. Fiscal Code:
  3. Cost:
  4. Project Title:
  5. Name and location of facility/contractor:
  6. General Objective:
  7. Problem
  8. Solution:
  9. Justification:
  10. Benefits:
    - a. Quantifiable benefits (S/I): \_\_\_\_\_ Basis:
    - b. Non-quantifiable benefits:
  11. Deliverables
  12. Funding Profile and Scheduled Technical Completion Dates:

<u>Fiscal Year</u>	<u>\$Costs</u>	<u>Month-Year</u>
_____		
_____		
_____		
Total		
- 

Figure 3. P-16 Form

---

13. End Items Supported:

- a. Primary
- b. Secondary

14. Key Milestone Dates:

- a. PEP Completion for primary end item
- b. MMT Completion
- c. Primary End Item TC
- d. Start of Full Scale Production
- e. Preliminary Design Criteria for Facility

15. Related MMT and Feasibility Demonstration Efforts:

- a. Project Nos. \_\_\_\_\_
- b. Initiation Date \_\_\_\_\_
- c. Completion Date \_\_\_\_\_

16. Plan for Implementation of Efforts' Results:

- a. When
- b. Where
- c. How
- d. Who
- e. Cost

17. Energy Resource Impact Statement:

18. Project Engineer:

- a. Name -
- b. Organization -
- c. Phone Numbers      AUTOVON \_\_\_\_\_      Commercial \_\_\_\_\_

Inclosure 1 - Environmental Documentation

---

Figure 3. P-16 Form (continued)

- Item 15: Related Efforts (15)--Here, the most common comments were that the referenced project was not valid (i.e., terminated), further detail of the relationship of the proposed effort to the related effort was desired, or additional related efforts were suggested. In one case, it was stated that the results of previous work on the project (i.e., for an ongoing effort) should be known. While this may be valid, there does not appear to be a place on the P-16 form for summarizing the status of previous work.

R&D (14)--This refers to the screening factor that states MMT projects cannot support research and development work. In 5 of these cases, the conclusion that the proposal involved research and development was in doubt.

- Item 6: General Objective (13)--The objective stated was not included in the approved list contained in the P-16 guidelines.
- Item 7: Problem (11)--Two main objections were noted: either more detail was needed or it was not a manufacturing problem.
- Item 12: Funding Profile (9)--These comments concerned inconsistencies within the P-16 or other data or that the costs were too high.
- Item 16: Implementation Plan (9)--The most frequent comment was lack of cost data on implementation; in two other cases, MMT costs rather than implementation costs were included.
- Item 11: Deliverables (7)--A general lack of, or clarity in, the identification of deliverables was cited here.
- Item 9: Justification (7)--More detail or making a better case was desired.

P-16 (6)--In this category, the comment was that system projects with more than one task require an overall P-16 plus separate P-16s for each task.

DUPE (4)--Four cases of duplicating previous work were found.

In addition, frequent reference was made to the limit of two pages for each Part I P-16 form submittal. The conclusions of this review are that the submitters should be reminded of what does and does not constitute MMT effort, and that the P-16 guidelines should be at hand when preparing submittals.

## 4.0 EVALUATION PARAMETERS

### 4.1 Introduction

All MANTECH projects are designed to satisfy an established Army need to improve a particular manufacturing process, technique, or equipment in a manner that has broad applicability within the Army as well as to other military branches and private industry. This need is derived from experience with, or analysis of, ongoing manufacture and maintenance of existing weapon systems, as well as the requirements imposed by new weapon systems entering the acquisition cycle. Typical candidate areas for the application of MANTECH resources are:

- Labor-intensive operations;
- Operations that generate high waste, particularly of scarce and high-cost material;
- Complex operations that can be consolidated, eliminated, or streamlined;
- Low production yield, where improvements will reduce rejection rates;
- Dangerous manufacturing operations, e.g., toxic materials handling, explosives, pollutants, and equipment; and
- General, high-cost areas, other than those cited above, where it is known that a particular manufacturing phase represents such a large percentage of costs that any improvement (management-material-process) will have a payoff in dollars saved.

Once a candidate area is identified as having the potential for the application of MANTECH resources, proposed manufacturing changes should be screened to insure that they meet the criteria for a MANTECH project. In brief, these criteria include the following:

- Does it address new or improved manufacturing technology that has not been applied previously?
- Has feasibility been demonstrated (laboratory, bench scale, or extrapolation of experimental data)?
- Is it production oriented, with the potential for broad/generic application?
- Should private industry pursue it on its own, or is it within the normal risk that industry might take?

- Is it likely that it might be available within the next 5 to 7 years without TACOM sponsorship?
- Is it likely to reduce costs?
- Does it duplicate any past or ongoing MANTECH projects?
- Is it definitely related to manufacture of the end item as opposed to the end item itself?

#### 4.2 Identification of Parameters

It is logical that a number of projects will be identified that satisfy the initial screening criteria; however, their total cost may exceed the financial resources available. Furthermore, it is always desirable to prioritize projects to insure that the appropriate amount of effort is devoted to the projects that will provide the greatest overall benefit. For these reasons, each competing project should be evaluated further. On this basis, need and cost savings obviously stand out as two important parameters for evaluating competing MANTECH projects. These two parameters, as well as others, can be grouped logically in areas that relate to each other:

- Criticality/Need
  - Increased Production
  - Advancement in State of the Art
  - Conservation of Critical Material
- Cost/Benefit
- Quality
  - Reliability
  - Maintainability
  - Availability
  - Durability
- Regulatory/Other
  - Safety
  - Reduced Pollution
  - Energy Conservation
- Risk
  - Likelihood of Success
  - Likelihood of Implementation

##### 4.2.1 Criticality/Need

Criticality/need can be rated independently. It is the most important parameter in evaluating TACOM MANTECH projects. It focuses on solving existing problems, or providing solutions for potential problems. It is almost an umbrella that covers all other evaluation parameters, whether they be objective or subjective.

Existing manufacturing bottlenecks, new system designs, new system performance requirements, mission support requirements (readiness, mobility) material shortages, and maintenance problems, contribute to the creation of a need for MANTECH projects. Even the criterion of economics can be expressed as a need (e.g., the need to reduce costs), although it is used more generally as a measure of merit in evaluating competing projects.

All projects should respond to a need, and the criticality of the need is a function of how well the current manufacturing process is suited to producing a weapon system or commodity end item that meets its technical performance or design requirements in a timely and economical manner. Is the proposed change really an improvement? Is it really needed? How urgent is it? Could it be used now if it were available?

#### 4.2.1.1 Increased Production

Increased production is not to be rated independently; it is to be incorporated in cost savings as a part of the economic analysis or criticality/need. One should differentiate between increases in the number of units produced at a given production rate, and the number of units produced due to increasing the rate of production. In the former case, the increase may be achieved by adding a second line or bringing another contractor on board, either of which may not qualify it as a MANTECH project. The second case of increasing the rate of production has to be the result of an improvement in process, technique, or equipment.

Although increased production is normally a laudible goal, the question has to be asked, "Why?" In general, it can be for one of two reasons. Either the current rate is inadequate to meet requirements reflected in the current Mission Statement, Army Material Plan, or other appropriate Army document, or costs can be reduced by producing more units (if required) in a given time, or a given number of units in less time.

The first reason, as discussed in the first paragraph above, would probably not qualify it as a MANTECH project even if another source of supply were required to provide insurance in the case of crisis.

The second reason may be reflected in the "criticality/need" parameter, and the benefits will certainly be included in the "cost/benefit" parameter.

#### 4.2.1.2 Advancement in State of the Art

Advanced state of the art can be rated independently if it is the only purpose and not covered by criticality/need. Advances in technology purely for the sake of technology are difficult to justify. Without an expressed need, there is a small likelihood of implementation and

these two parameters, need and likelihood of implementation, are very important for MANTECH projects. Furthermore, technological advances with no direct or immediate application are more likely to be in their feasibility stages, which may exclude them from the TACOM MANTECH Program. Although this parameter can be quantified objectively, it will probably be seldom used and one is cautioned not to give it double credit, i.e., if the "need" is to "advance...", rate the project under need and not under both "need" and "advancement."

#### 4.2.1.3 Conservation of Critical Materials

Conservation of critical materials is not to be rated independently; it is covered by criticality/need. The need to conserve critical materials or resources can, by itself, be a justification for a MANTECH project. However, this would be covered under the parameter of criticality/need. A MANTECH project is a solution to the need and it may embody the substitution of new or different materials, which may dictate a change in the manufacturing process, or just a change in the manufacturing process that eliminates waste.

#### 4.2.2 Cost/Benefit

Cost/benefit can be rated independently. Cost/benefit can be viewed from two aspects: (1) reducing costs and (2) using reduced costs in evaluating competing projects. In the first instance, either on the basis of intuitive observation or something more sophisticated like "cost driver analysis," a project is promoted purely to reduce costs. Reducing cost then becomes a "need," and one should establish a goal of how much costs reduction is desired.

More than likely, the project will be promoted based on one or more of the other quantifiable evaluation parameters. In this, the second aspect, cost/benefit becomes a measure of how well one proposed project compares with another. Because it is possible to derive a quantitative measure of merit, a comparison appears straightforward. However, two things should be taken into consideration: (1) limitations on the answer and (2) various ways in which the answer can be derived.

With respect to limitations on the answer, it is important to use "life cycle" costs in deriving the economic analysis, as there is often the temptation to look only at an immediate return on investment, which can prove to be small. It also would be beneficial to look at "net" savings based on either the complete end product or total weapon system. Complete reliance on the savings to investment ratio can lead to an emphasis of incremental, or percentage, savings that ignores larger absolute savings, particularly when the absolute savings are small in proportion to investment. It's easy to forecast a large incremental savings for a single project that may only be a small segment of the total production cycle and, therefore, insignificant in the total picture, while at the same time passing up



a smaller incremental savings from another project that would really be more significant in the total picture.

With respect to number of ways the answer can be determined, there are a number of economic measures of merit available to the analyst. These are discussed in detail in Section 5.0.

#### 4.2.3 Quality

Quality is not to be rated or considered independently because it is covered by other parameters. Quality is really the umbrella of all the other "ilities." It is difficult to envision something that is highly reliable, very durable, and easy to maintain, and yet is of poor quality. Also, if it has all these good attributes, it most certainly should enhance availability. Yet, "improved quality" is often cited as the justification for a MANTECH project. Furthermore, the reference is usually to the quality of the end item being produced--not the quality of the manufacturing change. This approach is not entirely valid, and the following distinctions should be made.

Quality must be "designed into" the hardware, whether it be the end item being produced or the process, technique, or equipment that produces it. There is no incentive or real payoff in "improving" quality beyond that required by the design. What is required is to "insure" that the designed quality is being met and maintained.

The primary focus in evaluating MANTECH projects should be on the quality of the manufacturing process, technique, or equipment. Test and inspection of this improvement change\* can only demonstrate the degree to which quality is being maintained. It would seem quite natural that a poor quality manufacturing method is likely to produce a poor quality end item. Therefore, in the event one starts to see a degradation in the quality of the end item, it may be wise for the hardware design engineer to collaborate with the production design engineer and ascertain the true cause. This definition, in turn, may dictate a new MANTECH need; the solution for which will again be evaluated according to other ilities.

A particular MANTECH project under evaluation may be the direct result of a "need" to insure quality of the end item. More sophisticated machinery, tighter controls, and increased automation are examples of changes that can increase precision and guarantee reproducibility or repeatability, thereby increasing yield. Quite often, however, these

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\*There also are end item peculiar "test and inspection" MANTECH projects that should not be confused with the test and inspection of the new manufacturing change. MANTECH test and inspection projects represent improvements in such areas as better screening, easier testing, and faster screening or testing.

projects are promoted under the military Quality Assurance Program, which is a separate DOD activity.

#### 4.2.3.1 Reliability

Reliability is not to be rated independently; it is incorporated in cost savings, which is part of the economic analysis. Reliability is often reflected in terms that relate to the performance of the end item being produced and not the manner by which it is produced. Producing in a manner that causes poor quality or high rejection rates does not affect the reliability of the end item which, if built to design, would have the same inherent reliability; it just makes the required quality more difficult, time consuming, and costly to achieve. For MANTECH projects, however, the measure of reliability should be restricted to the manufacturing process, technique, or equipment; mechanisms that are not large repetitive volume buys and that are not themselves subjected to lot sampling or reliability testing, although some of the piece parts that go into these mechanisms may be so tested.

By definition, if the manufacturing technology project is to be an improvement, it cannot degrade reliability, and the degree of improvement is very difficult to measure. Therefore, the best measure of a "more reliable" manufacturing process, technique, or equipment would be an increase in production rate resulting from either less down time (as mechanism is repaired) or lower rejection rates (higher yield). A new mechanism that just produces at a faster rate would not represent an increase in reliability.

#### 4.2.3.2 Maintainability

Maintainability is not to be rated independently; it is covered by economic analysis. By definition, any improvement in a manufacturing process, technique, or piece of equipment is not an improvement if it degrades maintainability. Again, one has to be careful to distinguish between maintenance of the production-oriented improvement, as opposed to maintenance of the end item being produced. For MANTECH projects, the emphasis should be on maintenance of the production change.\* The design of the end item being produced, as opposed to the manner in which it is manufactured, normally affects the maintenance of the end item.

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\*There are, however, some MANTECH projects that can enhance maintenance of the end item. For example, certain improved "test and evaluation" methods or equipment may be better able to predict failures, thereby extending the useful life of the end item, while still allowing for corrective action before the failure actually takes place.

Measures of the maintainability of the production change are reflected in attributes that contribute to the ease of repair, the extent to which it must be replaced, and how long will it last (mean time to repair or replace). These are life cycle questions that apply to the manufacturing change and not the end product. Any possible negative impact on maintainability of the end item would be grounds for canceling the project and, it is hoped, these relationships would have been defined in the R&D or feasibility stage prior to becoming a MANTECH project.

These measures should be reflected in the economic analysis as they are related directly to manufacturing operations and maintenance (O&M) costs and the costs of varying the production time and rate.

#### 4.2.3.3 Availability

Availability is not to be rated independently; it is covered by economic analysis. As with maintainability, an improved manufacturing process, technique, or equipment is not an improvement if it is not available. A highly precise and repeatable piece of machinery that is unreliable increases downtime. The emphasis for MANTECH projects should be on the availability of the improvement, which is largely a function of its reliability and maintainability, or MTBF and MTTR.

The case where there just "aren't enough" of an improved piece of manufacturing equipment (i.e., unavailability) is an insufficient reason to promote it as a MANTECH project and, therefore, should not be considered. The acquisition of additional normal manufacturing capability to expand the industrial base or to meet surge/mobilization requirements should be covered by normal production procurement funds.

#### 4.2.3.4 Durability

Durability is not to be rated independently; it is covered by economic analysis. Again, as with other ilities, one should assess the durability of the improved manufacturing process, technique, or equipment not the durability of the end item being produced.\* Will the new mold, die, etc., hold up as well as the item it is replacing, or will the automated handling equipment wear out before its manual counterpart?

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\*There are, however, some MANTECH projects that can enhance durability of the end item. For example, a change to a less corrosive material, or a new rubber compound that makes the end item more durable, may require a new manufacturing method to produce it.

#### 4.2.4 Regulatory/Other

##### 4.2.4.1 Safety

Safety can be rated independently. Compliance with OSHA regulations is a normal TACOM requirement, and manufacturing changes to accomplish this are normally funded with operations and maintenance, Army (OMA) or program funds. Given the other higher priority needs of TACOM, it is unlikely that a MANTECH project would be approved solely on the basis of this parameter. The benefit of improved safety, which may be quantifiable, would, by itself, probably not be significant enough to distinguish the project from others. Therefore, it is recommended that this be a secondary benefit, which if it occurred, might be helpful in rating two competing projects that were otherwise equal in all respects.

One also is cautioned not to give double credit for this parameter, i.e., if the principal purpose of the project is the "need to improve safety," then rate it according to need and not need plus additional credit for safety. If the sole purpose of the project is to improve safety, it may be possible to identify some financial savings due to increased productivity (fewer personnel lost work days) or lower overhead or burden rates (lower insurance or other compensation). This type of information should be reflected in the economic analysis.

##### 4.2.4.2 Reduced Pollution

Reduced pollution can be rated independently. Compliance with EPA regulations is a normal TACOM requirement, and manufacturing changes to accomplish this are normally funded with OMA or program funds. Given other higher priority needs of TACOM, it is unlikely that a MANTECH project would be approved solely on the basis of this parameter. The benefits of reduced pollution are hard to quantify as they are a function of the type of pollutant, the geographic area of the source, the amount of pollutant being discharged, and the environmental pathways for its impact. Therefore, competing projects cannot be separated based only on this parameter. Furthermore, quite often the incorporation of pollution-reduction equipment will cost more, so a savings to investment ratio calculation would not be a reason to promote the project.

Therefore, it is recommended that this be a secondary benefit, which, if it occurred, might be helpful in rating two competing projects that were otherwise equal in all respects. One also is cautioned not to give double credit for this parameter, i.e., if the principle purpose of the project is "need to reduce pollution," rate it according to need and not need plus additional credit for reducing pollution.

#### 4.2.4.3 Energy Conservation

Energy conservation is not to be rated independently; it is covered by economic analysis. The need to conserve energy is an important Army program given special consideration by the authority of the "Army Energy Program," AR 11-27 (Ref. 11). Energy savings can be realized through new breakthroughs in manufacturing improvement, that would therefore make them candidates for MANTECH projects. In most instances, however, energy conservation projects are of such a general nature that they are more appropriately funded with OMA funds.

Given other higher priority needs of TACOM, the opportunity for a project to be supported solely on the basis of energy conservation is quite small. However, all MANTECH projects present the opportunity for conserving energy and the projected savings in cost (which is the best measure of the benefit, as opposed to Btu's or gallons of oil) can be developed readily and should be incorporated into the economic analysis.

#### 4.2.5 Risk

Risk may be rated independently, but only to the granularity of high, low, or medium. Risk is an estimate of the degree of probability that a given MANTECH project may not achieve its stated purpose(s). In essence, it is merely a reflection of the uncertainty band around key evaluation parameters. For example, "Likelihood of Success" assumes an appreciation of the chance that the project's technical feasibility will not prove worthy of incorporation into full-scale production. Likewise, even if technical feasibility is proven, there is always some risk that the improvement may not be implemented for reasons that may be beyond the control of the MANTECH organization. This again reflects an uncertainty associated with the evaluation parameter "Likelihood of Implementation".

The economic analysis evaluation parameter is quite likely to contain some risk because financial estimates are merely projections at this stage. Furthermore, this risk may change with time--multi-year projects produce new data each year.

There is a positive correlation between "technical risk" and "economic risk." The greater the technical risk, the greater the likelihood that (1) it may cost more than projected, even if successful, and (2) that money may be provided continually to the project in pursuing modifications that may make it successful, when in reality, it should perhaps be dropped.

##### 4.2.5.1 Likelihood of Success

Likelihood of success can be rated independently. Proposed projects should present practicable alternatives to manufacturing processes, techniques, or equipment. The proposed project must have demonstrated

feasibility (e.g., laboratory or bench scale) prior to undertaking it as a MANTECH project. However, there are still problems that may be encountered as scale-up to production is not always as straightforward as one would like it to be. Yet, the project must demonstrate that the concept is suitable to direct transition to the mass-production manufacturing floor. This parameter is often expressed in terms of technical risk.

#### 4.2.5.2 Likelihood of Implementation

Likelihood of implementation can be rated independently. A committed sponsor who is willing to implement the proposed MANTECH project is a very important asset to the proposal. Although the cost of the MANTECH demonstration is absorbed by separate funding, the benefits will accrue to the Project Manager (PM) responsible for the end item commodity/weapon system. There can be problems with implementation even if the program office of the end item affected strongly supports a MANTECH project when it is proposed. After the project is completed and ready to be implemented, the management of the program office may have changed. There is then a good chance that the new PM may not be willing to accept the risk associated with "doing things differently than in the past." This requires placing continuing emphasis on implementation and coordination with the program office. So, emphasis should be placed on an "Implementation Plan," and a high degree of confidence that the improvement will be implemented.

There also is the chance that the improvement would be implemented without the benefit of MANTECH. In many instances the length of the budget cycle (2 to 3 years), the length of the demonstration project (up to 3 years), and the lead time to get the proven demonstration implemented (1 year estimated) are such that events may overtake the idea and it may become a reality without MANTECH. This raises the question, "What is the likelihood of the project being implemented without Army sponsorship?", a question appropriate to initial screening of MANTECH proposals.

### 5.0 ECONOMIC ANALYSIS

The calculation of economic measures of merit provides TACOM with a means of comparing the benefits of independent, unrelated MANTECH projects. This comparison is essential in prioritizing MANTECH projects and in identifying the most efficient allocation of limited financial resources.

Because of the somewhat a typical investment decision perspective of TACOM (for example, the orientation toward cost savings as opposed to profit maximization, differing time frames for investment versus realization of benefits from that investment, and substantial differences in scale of investment alternatives), the range of appropriate (for TACOM use) measures of merit is somewhat limited.

Measures of merit are presented in terms of ease of calculation, data requirements, interpretation, strengths and weaknesses of specific analytical approaches, and overall usefulness to TACOM.

#### 5.1 DOD and Army Economic Analysis Regulations and Directives

Within DOD, economic analysis and program evaluation for resource management are addressed specifically in DOD Instruction 7041.3 (Ref. 12). This instruction outlines policy guidance and establishes a DOD-wide framework for consistent application of economic analysis on proposed programs, projects, and activities. The fundamental rationale behind the DOD-wide emphasis on economic analysis is one of having to constantly make decisions as to how scarce resources should best be used, and to identify the implications of achieving a given objective in the most efficient and effective manner. Economic analysis is used to support decisions concerning trade-offs between alternatives, to identify the most cost-effective alternative when a range of alternatives exists, and to serve as a basis for establishment or change in priorities.

Specific to TACOM, AR 11-28 (Ref. 5) is consistent with DOD Instruction 7041.3 (Ref. 12). AR 11-28 establishes policy, procedures, and responsibilities for the application of economic analysis to ongoing as well as proposed, programs, projects, and activities. AR 11-28 defines economic analysis as the use of a systematic approach to the problem of choosing how to employ scarce resources and an investigation of the full implications of costs and benefits associated with alternative programs, missions, or alternative ways of accomplishing a given program. In the analysis, key variables are to be highlighted that are either identified as highly sensitive or that have the greatest effect on analytical results. The overall purpose of the analysis is to systematically examine all feasible alternatives, rank alternatives on the basis of benefit-to-cost relationships, and assist the decisionmaker in the identification of the most cost-effective alternative.

The essential elements for any economic analysis, as defined in AR 11-28 (Ref. 5), include:

- Identification of the mission-related objectives of the action(s) being considered;
- Specification of analytical assumptions and constraints;
- Listing of alternatives;
- Listing of benefits (outputs) for all feasible alternatives;
- Estimation of costs for all feasible alternatives; and

- Presentation of the relationship of benefits to cost of alternatives considered in the order of their respective economic performance.

Where appropriate, the analysis also will contain an assessment of the relative risk or uncertainty of success associated with each of the alternatives considered. Benefit estimates developed for each alternative are indicators of objective achievement and should be expressed quantitatively where possible. The analysis also should include important nonquantifiable benefits such as health, safety, security, and energy, if these factors are pertinent to a decision between alternatives. AR 11-28 (Ref. 5) states specifically that measures of performance and productivity indexes will be used to the maximum extent possible. In this context, the measures of economic merit (performance), discussed in Section 4.0 of this report, conform to the requirements in AR 11-28.

Of all the various elements and processes that must be included in the economic analysis, the accurate identification of benefits (outputs) is the most difficult. The analysis should concentrate on this aspect because estimates of project cost and timing are generally more rigorous.

## 5.2 Economic Measures of Merit

### 5.2.1 Discounted Cash Flow Techniques

Discounted cash flow (DCF) techniques incorporate explicit consideration of the time value of money, discounting future receipts and disbursements back to the present under an assumed discount rate (usually equivalent to the cost of capital). DCF techniques reflect the fact that a dollar today is worth more than a dollar 1 year from now; this is true because the dollar today may be invested so as to produce earnings during the intervening year. DCF techniques enable decisionmakers to compare equivalent estimates for cash flows of alternative investments at the same point in time.

The most widely used DCF techniques include net present value (NPV), internal rate of return (IRR), profitability index (PI), and savings/investment ratio (SIR). These DCF techniques can be further broken down into absolute (NPV, IRR) and relative (PI, SIR) measures of merit. Absolute measures of merit indicate the actual benefit obtainable from a given investment, whereas relative measures of merit indicate the ratio between the discounted receipts and disbursements or the profitability per dollar cost of the investment. Thus, the PI and SIR are benefit/cost ratios.



## 5.2.2 Absolute Measures of Merit

### 5.2.2.1 Net Present Value

The NPV for an investment alternative is the present value equivalent of its net annual cash flow (annual receipts less annual operating costs) minus the present value equivalent of its investment costs. In other words, NPV represents the present equivalent net profit for an investment. Mathematically, NPV can be determined from the following equation:

$$NPV = \sum_{t=0}^N \frac{F_t}{(1+K)^t} - \sum_{t=0}^N \frac{I_t}{(1+K)^t} \quad (5-1)$$

where  $F_t$  = Net flow of dollar benefits (or cost savings) in year  $t$ ;

$K$  = Discount rate;

$I_t$  = Capital investment outlay in year  $t$  ( $t=0$  indicates project initiation); and

$N$  = Lifetime of project, in years.

Note that the investments as well as the benefits, or savings, are likely to occur over a multi-year period.

If a project yields a positive NPV, the value to the investor increases by the amount of the NPV. (Conversely, if a project yields a negative NPV, the value to the investor decreases accordingly.) Thus, an investment project is considered economically attractive if its NPV exceeds zero. The decision rules under NPV analyses are to accept all independent projects whose NPV is greater than zero and to rank the investments in descending order of NPV.

### 5.2.2.2 Internal Rate of Return

The Internal Rate of Return (IRR) is defined as the interest rate that equates the present value of expected future net annual cash flows to the present value of the capital investment. IRR is frequently referred to as return on investment (ROI). Mathematically,

$$\sum_{t=0}^N \frac{F_t}{(1+R)^t} - \sum_{t=0}^N \frac{I_t}{(1+R)^t} = 0 \quad (5-2)$$

This equation is the same as Equation 5-1, with the exception that for IRR the equation is solved for the interest rate ( $R$ ) which equates the present value of the investments to the present value of the net annual cash flow. In practice, determining a project's IRR is done on an iterative basis. In general, Equation 5-2 cannot be solved for  $R$  in a closed form.

It is important to note that IRR does not measure the rate of interest earned on the initial outlay for a project. IRR projects the rate of interest that must be earned on the unrecovered balance of an investment so that the initial investment is exactly recovered (repaid) at the end of project life.

If a project's IRR, ( $R$ ), is equal to the discount rate or the cost of capital ( $K$ ), the investor exactly breaks even on the investment. When  $R > K$ , the investor has gained value, and when  $R < K$ , the value to the investor has decreased. The decision rule is, therefore, to accept independent projects where  $R > K$  and to rank mutually exclusive projects in decreasing order of IRR.

IRR is a technique that is useful in situations where knowledge about future interest rates is uncertain. Unlike NPV, IRR is calculated without assuming an interest rate. Calculation of a project IRR allows comparison with some established minimum attractive rate of return.

#### 5.2.2.3 Comparison of NPV and IRR

The strengths and weaknesses of NPV and IRR are treated together here because they are fundamentally identical and, under identical assumptions, will generate the same accept/reject decision for a project. The difference is in the focus of each: in NPV, the stream of annual net cash flows (costs and benefits) is discounted back to the present under an assumed discount rate, whereas the same equation for IRR is solved for the discount rate that equates the present net value of annual cash flow benefits to the present net value of investment costs. In the context of economic analyses performed by TACOM, both techniques are appropriate.

Under the NPV method, a TACOM project would be accepted if its NPV is greater than zero (i.e., the project has positive net present value). NPV also is used to rank mutually exclusive projects. From the mathematical formulations presented for IRR and NPV, if  $R > K$ , NPV must then be greater than zero. Accordingly, both approaches will give consistent accept/reject decisions. However, caution must be exercised when comparing projects of different size (capital outlay), duration, or if the annual net cash flows of one project are substantially different from that of another.

IRR is applicable even if the discount rate is known, such as in the TACOM case where the discount rate is specified by DOD. For TACOM, a project would remain in the running as long as its IRR is  $> 10$  percent. IRR and NPV are both useful for their difference in focus on the assumptions in an investment decision. When a conflict in project ranking using IRR versus NPV arises, the decisionmaker should generally rely on NPV because that measure indicates actual increases in value (benefits) stemming from a project, as opposed to IRR that

is, in effect, a derived interest rate indicating the potential return on investment, but which says nothing about actual dollar benefits.

One drawback in relying on NPV as a decision criterion for prioritizing TACOM MANTECH projects is the general tendency of NPV to favor large projects even though small projects also can generate large benefits. This tendency, attributable to the fact that NPV is an absolute measure as opposed to a derived ratio, can be overcome through analytical techniques such as incremental cost/benefit (profitability) analyses.

### 5.2.3 Relative Measures of Merit

#### 5.2.3.1 Profitability Index (PI)

The profitability index (PI), a benefit/cost ratio, is defined by the following:

$$PI = \sum_{t=0}^N \frac{F_t}{(1+K)^t} \div \sum_{t=0}^N \frac{I_t}{(1+K)^t} \quad (5-3)$$

PI shows the relative profitability of a project, i.e., the present value of benefits per dollar invested. Like NPV and IRR, it produces a measure of merit that can be used in ranking projects. The use of PI produces accept/reject decisions consistent with NPV measures of merit. However, NPV and PI can give different rankings for a group of projects evaluated using both techniques. This phenomenon occurs in mutually exclusive projects if differing scales of investment are compared. Table 3 provides an example that compares NPV and PI calculations; it illustrates the potential variation in rankings using both techniques.

When using NPV to rank alternatives, Project A would be chosen over Project B due to its higher NPV. However, on a relative basis, i.e., benefits per dollar invested (PI), Project B would be chosen. To overcome this apparent inconsistency in project ranking, it is necessary to normalize one project to the scale of the other. The classic techniques for normalization of investment scale have an implicit assumption of profit maximization over time. This assumption is inappropriate in the context of TACOM; accordingly, an alternative means of normalization must be developed for inclusion in the economic evaluation process.

#### 5.2.3.2 Savings/Investment Ratio

SIR is identical to the profitability index, but SIR is calculated for proposed projects whose benefit streams consist of cost reductions rather than increased benefits created as a result of the investment. Because the equations are identical, SIR will not be evaluated further in this section. The difference in terminology reflects a focus on

Table 3. Hypothetical Project Cost and Benefit Data

Year	PV Factor	<u>Project A</u>		<u>Project B</u>	
		Net Cash Flow( $F_t$ )	PV( $F_t$ )	Net Cash Flow( $F_t$ )	PV( $F_t$ )
1	0.9091	200.00	181.82	71.50	65.00
2	0.8264	200.00	165.28	71.50	59.09
3	0.7513	200.00	150.26	71.50	53.72
4	0.6830	200.00	136.60	71.50	48.83
5	0.6209	200.00	124.18	71.50	44.39
6	0.5645	200.00	112.90	71.50	40.36
7	0.5132	200.00	102.64	71.50	36.69
8	0.4665	200.00	93.30	71.50	33.35
9	0.4241	200.00	84.82	71.50	30.32
10	0.3855	200.00	77.10	71.50	27.56
			1229.90		439.31
			1230.00		439.00

PV Factor at 10% Discount Rate

Project A

Investment = 1000  
Net Present Value = 230

Project B

Investment = 300  
Net Present Value = 139

Comparison of NPV and PI Results

<u>Project</u>	<u>PV Costs</u>	<u>PV Benefits</u>	<u>NPV</u>	<u>PI</u>
A	1000	1230	230	1.23
B	300	439	139	1.46

$$PI_A = 1230/1000 = 1.23$$

$$PI_B = 439/300 = 1.46$$

public sector investment alternatives (for SIR) as opposed to the profitability of a potential investment in the private sector. Because the principal objective of TACOM in this respect is cost reduction in manufacturing processes, SIR is a highly appropriate measure of merit for use in the economic evaluation of proposed MANTECH projects.

In TACOM MANTECH investment alternatives, as contained in the P-16 exhibits and the command survey, several common characteristics of MANTECH projects were observed. These characteristics included

- Projects are usually independent,
- Generally similar MANTECH Program funding periods--usually 3 years,
- Generally similar periods of time required to implement MANTECH projects, and
- Project implementation generally remains in force for 12 to 15 years.

After evaluating TACOM MANTECH projects (as presented in the P-16 exhibit), it is apparent that the small differences in project lifetime will not introduce a significant problem into the economic evaluation and prioritization of proposed TACOM MANTECH projects.

#### 5.2.4 Payback Period

The payback period is the length of time required to recover the first cost of an investment from the net cash flows produced by that investment for an interest rate equal to zero. In other words, the payback period is the minimum time required for an investment to become profitable, ignoring the time value of money. In comparing investment alternatives, the payback period measure of merit indicates which alternative will be the first to recover its initial cost. Mathematically, the payback period is the number of years (N) until:

$$\sum_{t=0}^N (C_t - B_t) = 0 \quad (5-4)$$

where  $C_t$  = Costs in year  $t$ : and

$B_t$  = Benefits in year  $t$ .

Payback also can be calculated on a discounted basis but the basic flaw, as noted above, is still inherent in the calculated measure of merit. As noted in AR 11-28 (Ref. 5), payback is considered to be an inferior measure of merit because it ignores project benefit and costs once the cash outlay for the investment has been recovered. This

means that projects with long-term benefits but low initial benefits are less favored than short-lived investments. In general, experience indicates that this bias is unjustifiable and, in many cases, economically unsound. Nonetheless, the technique is simple to calculate and intuitively attractive to many decisionmakers. As such, it is recommended that it be used only as a supplementary method to the more rigorous techniques (e.g., NPV, IRR, PI). In instances where projects yield identical estimates of PI, IRR, NPV, or SIR, payback can be used as decision criteria to determine which investment should be made on the basis of most rapid cost recovery.

### 5.3 Comparison of Measures of Merit

#### 5.3.1 Data Requirements

NPV, IRR, PI, and SIR data requirements are identical. Information necessary to analyze projects based on these measures of merit includes: annual net cash flows (net benefits), project capital investment cost, discount rate as specified by DOD, and the number of years in the lifetime of the investment plus the life cycle length of the project as implemented. Payback period requires only the flow of annual net benefits and costs up to the time that the two are equal.

#### 5.3.2 Ease of Calculation

Again, there is very little difference in the ease of calculation between the four primary measures of merit listed above. Because the determination of IRR is an iterative process, its calculation is the most time consuming. However, with the widespread use of computers, large data sets can be manipulated easily and efficiently using any of these measures of merit. Calculation of payback period is the simplest measure to calculate, and this is a primary reason for its attractiveness to decisionmakers. However, it is crucial to keep in mind the caveats associated with it.

#### 5.3.3 Unequal Project Lifetimes

In comparing independent project investments (both private and public sector), the analyst is often confronted with project alternatives having differing economic lifetimes. When comparing such alternatives, it is necessary to equalize or normalize project lifetimes so that all alternatives are evaluated on a comparable basis. This is usually accomplished by adopting the longer lived project lifetime as the economic lifetime and repeating the shorter lived investment, i.e., replacement investing, so as to allow comparable periods of investment for analysis.

### 5.4 Conclusions

The measures of merit considered in this report range from overly simplistic (e.g., payback period) to fairly sophisticated treatments

of costs and benefits. Table 4 summarizes the measures of merit evaluated. Based on the range of measures evaluated, several highly desirable characteristics of an ideal measure of merit for TACOM use are identifiable:

- It must have a discounted cash flow basis,
- Both absolute and incremental aspects of an investment should be reflected in the measure of merit,
- It should be simple to calculate, and
- Its meaning should be clear and not subject to multiple interpretation.

All the measures of merit considered in this report are prone to at least one common weakness--all require the estimation of future benefits. Investment costs, in the context of proposed MANTECH projects, are fairly straightforward to estimate or are at least given, i.e., bounded. Benefits are, however, far more subjective and speculative because they are an integral element in all the measures considered and are most likely to be a source of potential error and subsequent misestimation. Thus, the remaining work of Task III will emphasize the development of guidelines for determining benefits.

The various techniques discussed here can be ranked in terms of the desirable characteristics listed and usefulness to TACOM in the evaluation and prioritization of proposed MANTECH projects. Ranking from most useful to least useful, they are:

- PI or SIR, as appropriate;
- NPV;
- IRR; and
- Payback.

Both the PI and SIR measures of merit come the closest to satisfying the needs of TACOM in terms of an economic measure of merit to be used for project ranking. They are incremental in nature and reflect the cost effectiveness per dollar expended. Payback period is not recommended for TACOM use because it does not factor into the analysis any consideration of project cash flows after the initial investment payback period is achieved.

Despite the scope of the economic measures of merit evaluated, there are at least two additional factors that must be reflected in the evaluation and ranking process; they are:

Table 4. Summary of Economic Measures of Merit

Title	Formula	Data Requirements*	Comments
Net Present Value (NPV)	$NPV = \sum_{t=0}^N \frac{F_t}{(1+K)^t} - \sum_{t=0}^N \frac{I_t}{(1+K)^t}$	$I_t, F_t, N, K$	Absolute measure of value generated for total investment. Accept investment if $NPV \geq 0$ for independent projects. Yields accept/reject decisions consistent with PI, SIR, and IRR. Does not rank alternatives consistent with PI and SIR if significant differences exist in project scale or timing.
Internal Rate of Return (IRR)	$IRR = \sum_{t=0}^N \frac{F_t}{(1+IRR)^t} - \sum_{t=0}^N \frac{I_t}{(1+IRR)^t} = 0$ Solve for R	$I_t, F_t, N$	Absolute measure of investment profitability. Accept investment if $IRR \geq K$ for independent projects. Yields accept/reject decisions consistent with NPV, PI, and SIR. Does not rank alternatives consistent with PI and SIR if significant differences exist in project scale or timing. Iterative solution process; should be computerized.
Profitability Index (PI)	$PI = \sum_{t=0}^N \frac{F_t}{(1+K)^t} : \sum_{t=0}^N \frac{I_t}{(1+K)^t}$	$I_t, F_t, N, K$	Incremental measure of value per dollar invested. Accept investment if $PI > 1$ for independent projects. Yields accept/reject decisions consistent with NPV, SIR, and IRR. Does not rank alternatives consistent with NPV and IRR if significant differences exist in project scale or timing.
Savings/Investment Ratio (SIR)	$SIR = \sum_{t=0}^N \frac{B_t}{(1+K)^t} : \sum_{t=0}^N \frac{C_t}{(1+K)^t}$	$B_t, C_t, N, K$	Incremental measure of net savings per dollar invested. Accept investment if $SIR > 1$ for independent projects. Yields accept/reject decisions consistent with NPV, PI, and IRR. Does not rank alternatives consistent with NPV and IRR if significant differences exist in project scale or timing.
Payback Period (PB)	$PB = \sum_{t=0}^N (C_t - B_t) = 0$ Solve for t	$C_t, B_t$	Does not consider benefits accrued after repayment of initial investments. As typically applied, does not recognize time value of money. Does not yield accept/reject decisions for project rankings consistent with other measures of merit. Can be used as secondary measure of merit to rank projects having similar measures of merit. Easy to calculate.

\*Definitions of parameters used in measures of merit calculations (for TACOM evaluation purposes,  $F_t = B_t$ ):

- $I_t$  = Capital investment (can occur over 1 or more years and includes capital costs of implementation).
- $F_t$  = Annual net cash flows accruing from investment in each year of investment lifetime.
- $N$  = Number of years in investment lifetime (for TACOM, includes initial investment period, and lifetime of production process where TACOM MANTech project is implemented.)
- $K$  = Discount rate (TACOM is directed).
- $C_t$  = Annual costs attributable to project investment.
- $R$  = Internal rate of return (interest rate that exactly equates the present value of project net cash flows to the present value of project capital investment; in effect, the project-derived discount rate).
- $B_t$  = Annual benefits attributed to the project.



- Economic and technical uncertainty and risk and
- Benefits that are nonquantifiable in economic terms.

Economic uncertainty can be accommodated by producing estimates of high, low, and most probable levels and timing of costs and benefits. When combined with estimates of probability for each of the three levels, probabilistic estimates of PI or SIR can be developed.\* Technical risk can be accommodated in a similar fashion. That is, estimates of high, most probable, and low degrees of technical risk, together with the probability of their occurrence, can be developed and incorporated into the evaluation process.

Benefit types (project outputs) that resist straightforward expression in terms of cost should be reflected in the overall project evaluation process despite the fact that some outputs are exceedingly difficult, if not impossible, to express in dollar terms. AR 11-28 (Ref. 5) states that benefits in this general category should be presented with the economic evaluation so that estimates of project output (i.e., indicators of objective achievement) are available to the decisionmaker. Further, difficulty or inability to quantify outputs is not a basis for disregarding output analysis. These benefits should be included when analytically and economically feasible. Heightened readiness capability is an example of this type of problem. It may not be readily expressed in terms of dollar benefits, yet the estimated percentage increase in readiness and the necessary investment can be presented. Such estimates have material value in that they provide the decisionmaker with at least some basis for determining the allocation of limited resources.

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\*Taken one step further, sensitivity analyses can be conducted to address economic uncertainty. These analyses involve focusing on the assumption(s) in the analysis (usually benefits) about which the least is known. That particular benefit or cost is varied by +5 or 10 percent, for example, and the measure of merit is recalculated. These evaluations reveal the sensitivity of a project's NPV (or other measure of merit) to misestimation of a variable that also can be accommodated by project evaluations. That is, estimates of high, most probable, and low degrees of technical risk, together with the probability of these occurrences, can be developed and incorporated into the evaluation and project ranking process.

## LIST OF ACRONYMS AND ABBREVIATIONS

AFSC	Air Force Systems Command
AVSCOM	Aviation Systems Command
AFWAL	Air Force Wright Aeronautical Laboratories
AMCCOM	Armament, Munitions, and Chemical Command
AMMRC	Materials and Mechanics Research Center
ASD	Aeronautical Systems Division
BMO	Ballistic Missile Organization
CAM	computer-aided manufacture
COCO	contractor owned contractor operated
DARCOM	U.S. Army Material Development and Readiness Command
DCF	discounted cash flow
DDR&E	DOD research and engineering
DMT	Directorate of Manufacturing Technology
DOD	U.S. Department of Defense
EPA	Environmental Protection Agency
FYDP	five-year defense plan
GOCO	government owned contractor operated
GOGO	government owned government operated
IBEA	Industrial Base Engineering Activity
IRR	internal rate of return
MACI	Military Adaption of Commercial Items
MANTECH	Manufacturing Technology Program
MICOM	Army Missile Command
MMT	Manufacturing Methods and Technology
MTAG	Manufacturing Technology Advisory Group
MTBF	mean time between failure
MTTR	mean time to repair
NAVMAT	Naval Material
NMCIRD	Naval Material Command Industrial Resources Detachment
NPV	net present value
OMA	operations and maintenance, Army
OSHA	Occupational Safety and Health Administration
PA/OMA	procurement appropriation/OMA
PEM	Production Engineering Measures Project
PEP	producibility engineering and planning
PI	profitability index
PM	Project Manager
R&D	research and development
RAM-D	reliability, availability, maintainability, durability
RDT&E	research, development, testing, and evaluation
RFP	Request for Proposal
SD	Space Division
SIR	savings/investment ratio
TACOM	U.S. Army Tank-Automotive Command
TC	technical completion
TECHMOD	technology modernization

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